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Page 230, line 32, for "*Engineering News-Record* of August, 1924" *read* *Engineering Record*, August 29, 1914, p. 243-244.

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THE VALUE OF IMPROVED PREPARATION OF BITUMINOUS COAL*

By Col. Warren R. Roberts†

INTRODUCTION

The advance notice of this meeting announced the title of this paper as "The Value of Improved Preparation of Pittsburgh Coal." I do not, however, wish to limit my discussion of so important a subject to the coal of any one district or from one seam, for the reason that coal from almost any seam and from practically all localities may be so greatly improved by adequate preparation that we may greatly increase the usefulness of the facts we present by giving them a general application. The arguments indicating the value of improved preparation are essentially the same for coal from any district. We will therefore conserve our efforts, if we broaden our subject and discuss "The Value of Improved Preparation of Bituminous Coal."

As we proceed we will specifically mention any reasons for better preparation of Pittsburgh coal which do not apply elsewhere, or conversely note any arguments given which would not seem to apply for the Pittsburgh field. I wish also to preface our discussion of this subject with some observations on the causes which seem to have so long retarded the proper preparation of bituminous coal in our country. If these observations are based on facts, we may be able from a careful consideration of them to draw conclusions that will assist us in more quickly bringing about the adequate preparation of one of the greatest commodities our nation produces. I consider this phase of our subject quite as important as to furnish the facts regarding the value of improved preparation. This statement is based on both my experience and observation on the introduction of any advance in practice in any industry. It requires a diligent and intelligent effort on the part of some considerable group of men to introduce a marked improvement in any industry. I therefore wish to impress on the members of this Society, on coal-mining engineers generally, and more urgently on the engineering and technical staff of our bituminous coal companies, that the early adoption of improved preparation, with its many benefits, will depend largely on their attitude in the matter.

*Presented September 29, 1925. Received for publication December 15, 1925.
†President, Roberts and Schaefer Company, Engineers and Contractors, Chicago

While suggestions for improved preparation do often originate with the sales department, due to contact with the consumer and his frequent complaints regarding impure coal, with the attendant demand for rebates, and in many instances refusal of further shipments, such complaints must necessarily be passed on to the general office which, in turn, sends them to the operating officials where, unfortunately, they usually lodge. When such complaints do receive serious consideration, the engineering and technical men are called in to remedy the defects, and this is the opportune time to demand better preparation.

This is no exceptional case I have outlined, but is of constant occurrence with a large majority of the producing companies. I could readily give innumerable illustrations to substantiate these statements, but, as you all know they are facts, I will not consume your time in mentioning them.

CAUSES OF DELAY IN BETTER PREPARATION

I shall mention only a few of the major causes which occur to me as having so long delayed an adequate preparation of our bituminous coal.

1. The vastness of our resources in this commodity and its very general distribution over the country have made us very wasteful in its production. This wastefulness applies to almost every feature of mining bituminous coal. We are all familiar with our prodigality and are just beginning to realize the enormity of our crime. It is encouraging to note that this realization is bearing fruit in improved practices in many phases of mining and we can only hope that the movement will gain momentum as the benefits and economies of these improvements are brought home to the operator.

2. The general ignorance and indifference of consumers of bituminous coal in the past have doubtless been the greatest factor in retarding improvement in the product they purchase. Until quite recent years the domestic consumer bought largely on price, with the exception that he was very partial to lump coal, seeming to enjoy the privilege of breaking up large lumps. In fact, he has not yet recovered from this exercise which has become a habit with him. Also, until recently and even now, our railroads and many large industrial consumers have shown very little appreciation of quality in the coal

they purchase. Here again, however, there is much encouragement, and many operators can testify they are being paid a premium for better coal.

3. The indirect method of marketing bituminous coal through agencies, jobbers, brokers, etc., down through the retailers has had a marked influence in retarding improvement in quality. It is an obvious fact that increasing the number of hands through which a commodity passes before it reaches a consumer not only adds to its final price but makes it difficult for the producer and consumer ever to reach an agreement of price based on quality.

There is encouragement, however, in knowing that there has, in recent years, been a very great increase in the percentage of coal marketed by the producer through his own agencies.

4. The lack of capital to make investments required for better preparation has, until recent years, been a very important factor in holding back such improvements even when the investment for such improvements was entirely warranted. Here again, and especially since the war when a great deal of capital was accumulated by the operators, there has been a decided improvement; and, generally speaking, operators can now secure capital for such improvements as can be shown to be a good investment.

5. Overcoming the inertia of precedent retards progress in every line of human endeavor. Coal producers only a few short years ago knew nothing of the value of preparation. Coal was then sold largely on a run-of-mine basis with no preparation. It required quite a long, diligent compaign to educate such operators to an appreciation of improved preparation. However, these early producers of bituminous coal have mostly been succeeded by men having many advantages that the earlier producers lacked, and who consider carefully all propositions presented for giving them an improved product.

VALUE OF PREPARATION

VALUE TO THE PRODUCER

This would appear to be the more vital part of our discussion for the reason that the producer must take the initiative in the matter of improved preparation. We must, however, show the benefits that accrue to the consumer, so that the producer may pass on the charges for any increased cost due to expenditures for improvements, plus a

profit. The facts also on which we base increased value of the product are in the main the same, but we must discuss these facts from a different viewpoint, and have therefore subdivided the subject.

Enlarging the Producer's Markets. Doubtless the most appealing suggestion that could be made to a coal producer at the present time, when many mines are idle and others running part time, is some method by which he may increase his sales and thereby his production, and through this increased production show increased profits. From my observation and experience of 25 years it is evident that larger markets follow better preparation. This statement is based not only on the experience of individual operators, but on the benefits that have accrued to entire districts that in the past improved their preparation. The preparation here referred to consisted, in the first place, of properly sizing the coal so that it could be used to the best advantage for various purposes. This preparation was followed by removing a part of the impurities first by hand picking some of the larger sizes, and in certain instances and for particular purposes, cleaning the nut and slack coal mechanically.

This gradual improvement from the marketing of the crude product that nature gave us has gone on slowly for the past 25 years until now a considerable percentage of our production of bituminous coal is cleaned more or less thoroughly. This percentage of our improved product, however, is restricted quite largely to certain districts that earlier saw the benefits of improved preparation or, from the nature of their product or the market that it had to satisfy, required improved preparation.

Increase in the Producer's Profits. Enlarging a producer's markets enables him to increase his production and thereby lower production costs, and, even with no advance in selling price for the improved product over and above an increase to cover the cost of better preparation, expenditures for better preparation make for profit. We have frequently made extensive improvements for producers who asked only for the profit to accrue from the above economy. We have, however, built many plants for improved preparation where we have the testimony of the operator that he received not only the increased profit above mentioned, but also materially increased the selling price of his

improved product over and above the additional cost of preparation. In several instances, in widely separated fields, and for varying markets, the increased value of the product from better preparation was most gratifying to the operator.

We regret that it is not allowable for us to mention the individual companies and mines where such improvement has shown such gratifying results, but operators are very adverse to advertising any prosperity that comes to them through such efforts, as they are anxious to keep the lead on their competitors as long as possible. In verification of these statements, however, we answer the questions which the president asks his general manager when the latter puts up to him a proposition involving expenditure for improved preparation—will the increase in sales and the increase in prices warrant the expenditure to obtain these benefits and also show us a good profit? We have to show the figures to answer these questions satisfactorily practically every time we secure a contract for such improvements.

Another source of material benefit and economy to the operator consists in better-satisfied customers, less sales resistance and therefore less expense in selling, the retention of customers instead of hunting new ones, the saving of rebates in adjustments for unsatisfactory coal, and many other small economies that make for profits.

In making improvements for better preparation we invariably improve the entire preparation plant, even though an entirely new plant is not built, and thus put the operating plant in a condition for steadier and more economical operation, which, in turn, reduces production costs.

These are only a few of the major benefits to the operator from improved preparation, but should be sufficient to awaken a more widespread interest in such improvements.

VALUE TO THE CONSUMER

The more refuse removed from the consumer's coal at the mine the less freight he will pay on dirt, which we all know does not produce heat in any furnace.

Clean coal, as compared with coal and refuse, materially increases the capacity of the consumer's furnace, saves depreciation in his grates and furnace, and requires less careful attention in firing; in fact, the consumer tells us he is often "cussing" the man who sold him his dirty

coal as well as the man who produced it.

There can be no doubt whatever about the benefits of clean coal to the domestic consumer, and yet he is the consumer who least appreciates the real merit of clean coal. He must therefore be educated to its value.

All of the above statements regarding the benefits to the domestic consumer apply equally, only in larger ratio, to railroads, industrial plants, and other large steam producers.

Not long since, we ran a test on a car of coal for steam purposes—a coal which carried a $2 freight rate and where the saving in the freight on the refuse alone was sufficient to carry interest on the investment, depreciation, maintenance and operation; leaving all the other benefits, such as improved capacity of furnace, less depreciation on grates, furnace walls, etc., handling of this refuse away from the boilers, and many other incidental expenses, clear gain to the consumer.

This test and report were made for an operator-consumer. We have made many other such tests for operators, which have been passed on to consumers, showing most excellent results. The consumer handles this same dirt several times—first, into his coal bins, then into his furnace, and finally he has to cart away all the surplus dirt in the increased amount of ash and cinders.

INCREASED VALUE OF CLEAN COAL FOR COKING PURPOSES

There seems to be no doubt as to the increased value of clean coal for coking purposes, and all we have to establish is the extent of this increased value. This is difficult to state definitely, as there is a considerable diversity of opinion on the subject. I can give only a few figures that have come under my personal observation.

We recently ran a test on coking coal for one of our clients, and in discussing the results one of the officials of the company stated that for one per cent. reduction in ash in the raw coal; the increased value of this coal for coking purposes was 30 cents a ton.

In discussing this subject with many other clients we have learned that they use figures varying all the way from 10 cents up to 50 cents a ton for one per cent. reduction in the ash. It would therefore appear that the definite statement by this official mentioned above was a fair sample of the consensus of opinion.

In connection with reducing the ash of coal for coking purposes, it is often important also to reduce the sulphur content, especially where the sulphur runs above one per cent. Incidental to the cleaning process, it is often possible to make a material reduction in the sulphur content. This, however, depends largely on the form in which the sulphur occurs in the coal.

Many tests have been made on coal for coking purposes where the reduction in ash ran from two to three per cent., and often higher. Using the figures given above as a basis for computing increased value in the cleaned coal, it is apparent that with such reduction in the ash, increased value in the coal for coking purposes is very material. We believe a day is not far distant when the consumers of coal for this purpose will demand a coal as clean as the present art can give them, which it is perfectly evident they are not obtaining at the present time.

VALUE TO THE NATION

Improved preparation means conservation for the nation, all the way from mine to destination. We produce some 500,000,000 tons of bituminous coal per annum. Suppose that at the mine we removed only three per cent. of refuse from this production, we thereby save freight on 15,000,000 tons of material worse than useless to the consumer. We have plainly shown above that refuse in coal is harmful and detrimental for whatever purpose the coal may be used. We will be conservative, however, and figure for the nation only the saving in freight on 15,000,000 tons of refuse, say at an average freight rate of $2 a ton. This shows a national saving of $30,000,000 per annum. Certainly this is a real national economy.

It is common knowledge that for many years the coal industry has had anything but an enviable reputation with the general public. This lack of confidence and good-will of the public towards this industry is based on several major grievances which the public holds against this industry. We, as a part of this great industry, are interested in correcting all these grievances and thereby re-establishing this industry in the confidence of the public.

Only one of these grievances, however, is of interest to us in this particular discussion, and that is the quality of coal which we should furnish the public.

This industry has not, in the past, and even at present does not,

furnish the public with a product in keeping with that which is advertised, or which the consumer may reasonably expect to receive. We confidently believe that if this industry had more pride in the product which it furnishes the public, and was always careful and diligent in furnishing the cleanest and best product possible under the present art of preparation, one of the chief grievances of the public against it would shortly disappear.

This statement is based on many years of close observation and a thorough knowledge of the relationship between this industry and the public. It has been one of my earnest and constant efforts to eliminate this particular complaint, in which we think the public has a great deal of justification.

DISCUSSION

Newell G. Alford, *Chairman*:* We have listened to a very interesting paper. We would now like to hear some discussion of the paper.

Col. Warren R. Roberts: I will open the discussion by reading from the letter I received from Mr. Newell G. Alford, asking me to submit certain additional facts and figures not contained in my written paper, a copy of which I had already forwarded to him. I therefore prepared certain data to answer these questions by Mr. Alford and which will supplement certain statements made in my paper.

After expressing appreciation of my paper, Mr. Alford asked for figures on the following points:

1. Cost of preparation for ascending and descending degrees of perfection.
2. Possible additional earnings to the operator through proper sizing.
3. Possible additional earnings to the operator through cleaning to an economical reduction of impurities.
4. Data on the spread in sales prices for run-of-mine and sized bituminous coal.

It is not possible to answer the first inquiry, as it is entirely too general. Moreover, I do not believe that the best engineering practice in coal preparation makes provision for various degrees of perfection in preparation. When expenditures are made for a better preparation of coal they should provide for the best preparation possible, with a reasonable expenditure based on tonnage requirements, etc.

In answering the second question, I wish to call attention first to the fact that the sizing of coal into various grades was the first form of coal preparation in this country. For some years past, certain districts, especially Illinois and Indiana, carried the sizing or grading of their coal to quite an extreme. In Indiana it is quite customary to make from three to five grades, and in Illinois the standard sizing is for seven grades, although a great many of the mines in this state make only from four to five sizes. This practice of making several

*Engineer, Howard N. Eavenson & Associates, Pittsburgh.

different sizes of coal grew up largely out of the severe competitive conditions under which coal producers were constantly endeavoring to find some new market for their coal and thus enlarge their production, or as sales talk against their competitors who did not make the sizes which they offered for sale. Under these influences sizing has gone on to the extreme in these two states indicated above. There were a great many experienced operators in Illinois and Indiana who did not approve of this competition in making more sizes, and who believed that it added a burden to the industry which was not paid for by the markets obtained. My contact with operators in these states convinces me that there is a growing sentiment against this practice of making numerous sizes of coal without any further preparation.

Referring more particularly to the coal in the Pittsburgh district, I am convinced that sizing of the coal here as practiced in Illinois and Indiana without further preparation will not be of great benefit to the producers. This statement is based on tests which we have made for operators in the Pittsburgh district, and the northern fields of West Virginia and on the statement of many coal producers in these districts. When the coal in these districts is sized only into certain grades and not cleaned, it is difficult to find a market for these various sizes due to the fact that they carry too high a percentage of impurities. We can confirm this statement with an illustration from a recent test we ran for one of our clients in northern West Virginia. He shipped us a car-load of two-inch by one-inch nut coal that had been carefully sized at his tipple and also carefully hand picked on a picking table where 10 men were employed. This car-load of coal thus prepared was cleaned at our testing plant near Chicago on one of our new air tables and we removed more than nine per cent. of refuse. This test was positive proof that it was not practicable to hand pick nut coal, and also indicated that sizing of this coal without cleaning was not beneficial.

The owner of the mine who furnished us coal for this test stated that he was not able to market this nut coal even after it had been hand picked, and this was his reason for seeking some method for properly cleaning this coal. We therefore feel justified in making the broad statement that hand picking of nut coal at any mine is not economical. Nut coal and all the smaller sizes should be cleaned mechanically.

We can give you another illustration from a mine in central West Virginia, where much more elaborate sizing and cleaning tests were made, which will further prove the statement we have made above.

We received at our testing plant a car-load of two-inch screenings, which we first carefully sampled and tested, and found that the average ash in this car-load of coal was 12 per cent. This coal was then carefully sized into nut (two inches to one inch), pea (one inch to ¼ inch), slack (¼ inch to 1/16 inch), and dust (1/16 inch, and under). This coal was then very carefully sampled and analyzed, and the nut coal contained an average of about 18 per cent. ash; the pea coal, about 15 per cent. ash; the slack, about eight per cent. ash; and the dust, about six per cent. ash. This coal was then carefully cleaned on our air tables, each of the above sizes separately, with the following results:

The cleaned nut coal had been reduced to about eight per cent. ash; the pea coal to about seven per cent. ash; and the slack to five per cent.

The coal below 1/16 inch, containing six per cent. ash, was not cleaned. The average ash in the three sizes cleaned and the dust not cleaned reduced the ash in the combined sizes from the 12 per cent., mentioned above as the average for the car, to seven per cent.

These figures indicate conclusively that for the nut and pea sizes this coal would not be marketable when sized and not cleaned. We believe this is a fair car sample of coal not only from this particular mine but from that district.

We believe this answers question 2 quite thoroughly.

Referring to question 3, as to the possible additional earnings to the operator through cleaning to an economical reduction of the impurities, it would seem to be apparent from the above tests and analyses that cleaning such coal would be highly beneficial, but we will give a few additional figures in support of this conclusion, and in answer to question 3.

The result of the test of this car of coal induced the owner to have us prepare for him a design and estimate on a dry-cleaning plant from which he could make an estimate of the benefit of such a plant for cleaning this coal. After a very careful consideration of the cost of the plant, including its cost of operation, maintenance, etc.,

and the benefit to the coal, he decided to build the plant. In further answer to question 3 we will give another illustration based on a car-load of coal from the Pocahontas field of West Virginia, where tests very similar to those outlined above were made, and which resulted in our being awarded the contract for cleaning the two-inch screenings at this mine. The estimated cost of this plant complete, including the elevator to bring the two-inch screenings from the tipple to the dry-cleaning plant was $120,000.

This plant has a capacity of 200 tons an hour. Assuming an eight-hour day and 250 working days a year, the plant will clean 400,000 tons of coal at an anual cost of $35,200, as indicated below:

Interest on investment at six per cent	$ 7,200
Estimated operating expenses, approximately	16,000
A liberal depreciation over a 10-year period	12,000
Total interest, depreciation, operation, etc.	$35,200

This indicates an approximate cost of nine cents a ton for cleaning this coal.

We have several smaller cleaning plants in successful operation, which have been running for six months to two years, where the costs outlined above have averaged from 12 to 14 cents a ton. Based on the relatively smaller capacity of these plants, these figures on actual operating costs check up fairly close to our estimated cost above for this larger plant.

There is one additional feature of cleaning which must be taken into account in arriving at a basis of values of the raw and cleaned coal—that is, the loss from refuse removed. Based on the few plants which we have built and have in operation, and on the many tests we have made in car-load lots of coal, it would be fair to assume a loss of, say, five per cent. It is also necessary to assume some average mining cost per ton. We believe that for the district under discussion $2 a ton would be a fair average cost, and therefore the loss due to removal of refuse by cleaning would amount to five per cent. of $2, or 10 cents a ton. This 10 cents loss in refuse added to the above mentioned cost of cleaning the coal in this plant (nine cents) makes a total loss and cleaning charge of 19 cents a ton.

If we were to select one of the smaller plants and take even a

cleaning charge of 15 per cent. a ton, this, added to the 10 cents loss of refuse, would make 25 cents a ton.

To arrive at a final conclusion as to the additional profit to the operator from the cleaning process, we must next assume a market price for the coal sold uncleaned, and sized and cleaned as will be done by this plant. We will, therefore, take the Cincinnati market at the present date as a fair basis of selling prices. Last week the Cincinnati quotations, f.o.b. mine, were as follows:

Lump coal, per ton	$5.00
Run-of-mine, per ton	2.50
Two-inch screenings, per ton	2.00

We must now give you the percentages of each size of coal as produced at this mine before the dry-cleaning plant was built, which were as follows:

Lump coal	20 per cent.
Egg coal	15 per cent.
Two-inch screenings	65 per cent.

The two-inch screenings which were sized and cleaned at our testing plant, and which amounted to 65 per cent. of the run-of-mine coal, were as follows:

Nut, two-inch to one-inch	10 per cent.
Pea, one-inch to ¼-inch	30 per cent.
Slack, ¼-inch to 1/16-inch	30 per cent.
Dust, 1/16-inch, and under	30 per cent.

Taking the percentage of lump coal as given above at 20 per cent., the egg coal at 15 per cent., and the percentages of the two-inch screenings given in the sizing test just above, and adding together the percentage of nut and pea, assuming that these two sizes might be sold together, and also adding together the slack and dust, assuming these would be sold together, we have 40 per cent. of the nut and pea, which equals 26 per cent. of the total run-of-mine, and we have 60 per cent. of the slack and dust, which equals 39 per cent. of the run-of-mine.

The following computation with these percentages gives the selling price of the sized and cleaned coal:

Lump coal, 20 per cent., at $5	$1.00
Egg coal, 15 per cent., at $4.50	0.68
Nut and pea coal, 26 per cent., at $3	0.78
Slack and dust coal, 39 per cent., at $2	0.78
Average selling price	$3.24

This average selling price of $3.24, less the cleaning charge, plus the loss of refuse of 19 cents, leaves a net selling value per ton of the sized and cleaned coal of $3.05, as compared to $2.50 a ton for the same coal marketed as run-of-mine.

We can well afford to discount the sized and cleaned coal another five cents a ton to make the estimate more conservative, and you will see that we still have a net additional profit of 50 cents a ton on this coal. This would appear to be a safe margin of additional profit which would warrant a coal producer investing in a plant to secure this preparation.

I regret that I do not, as yet, have sufficient data on sizing and cleaning coal from the Pittsburgh district to enable me to bring closer home to you the benefits of sizing and cleaning your coal. We have run some such tests and will have the information available a little later. I have, however, the partial data on two cars of coal tested from the Johnstown district; one car from the Lower Kittanning, and one car from the Upper Kittanning. The test on the Lower Kittanning indicated a total reduction from the run-of-mine coal of 3.4 per cent. Coal below 1/16 inch was not cleaned, but for the portion of the coal above 1/16 inch which was cleaned the rejections were 4.1 per cent. The rejections from cleaning the car of Upper Kittanning from the total run-of-mine was 3.1 per cent., and the rejections for the portion cleaned, 4.7 per cent. Both of these figures, even on the run-of-mine basis, are somewhat higher than the rejections of three per cent. which I assumed in my paper as a basis on which to figure savings in freight rates, if the bituminous coal in the United States were all cleaned at the mine before shipping.

Mr. Alford's fourth request was for data on the spread in sales prices for run-of-mine and sized bituminous coal. I have already answered this question briefly in my discussion of question 2. However, if any of you wish to make more elaborate comparison in this

spread of prices you can obtain the weekly selling prices of coal of various sizes from the coal journals, and, following the methods outlined in this discussion, easily obtain results for any particular grading of coal and for whatever market you may select.

GRAHAM BRIGHT:* The proper preparation of coal does one very important thing—that is, it produces a uniform product. Unprepared coal is liable to be very erratic and is often the cause of many complaints sometimes not justifiable, as the particular car or part of the car containing an excess of impurities may not be a fair sample, but an accidental occurrence. A uniform product will tend towards a uniform demand with steady market and reduced costs.

In preparing and cleaning coal it does not pay to go too far in ash reduction if additional expense is involved. The consumer is willing to admit that for every one per cent. reduction in ash the value of the coal is increased a definite amount, but in most cases is unwilling to pay for any reduction below six or eight per cent. The greater demand, the satisfied customer, and the more uniform operation of the mines will more than pay for the cost of preparation, even if the price obtained is not much more than that obtained for unprepared coal.

The advent of the mechanical loader will make the preparation of coal at the tipple a necessity, since the mechanical loader can not discriminate, but loads everything in front of it, and the refuse must be discarded at the tipple.

N. F. HOPKINS:† I should think that in the last analysis the cost of treating coal should be something less than the freight on the dirt and the cost of handling the ash. Of course, a coal with a great amount of ash of a low fusing point is difficult to burn. Where the freight rate is low, it might not pay to go to too great an expense for ash removal.

COL. WARREN R. ROBERTS: It is rather difficult to answer this question, due to the fact that coal from any plant is shipped to various destinations with a varying freight rate. It is apparent, however, that

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†Harrop & Hopkins, Pittsburgh.

the greater the distance shipped and the higher the freight rate, the greater will be the spread between the cost of cleaning and the saving in freight by shipping clean coal.

I can cite one example where we made very careful and extensive tests on an Illinois coal which was being shipped to Chicago for exclusive consumption by the producer. This test was on two-inch screenings, which carried a $2 freight rate to Chicago. The test indicated that we could remove eight per cent. of refuse, thereby saving eight per cent. of $2, or 16 cents a ton, freight on refuse. This producer contemplated building a large plant and thus the cleaning cost would not exceed the figures given above for a large plant—nine to ten cents a ton. Please note also that this comparison does not include the many other savings which the client included in his estimates of benefits in cleaning the coal, such as increased boiler efficiency, saving in repairs on grates and furnaces, and an extra cost of removing eight per cent. additional ash refuse. A conclusion from the test was that the cleaning would be highly beneficial.

I should like to confirm Mr. Bright's opinion that the securing of uniform ash in the coal is the important consideration, rather than an endeavor to secure a very low ash content.

In the illustration I have given in my cost analysis above, this particular client did not wish to make expenditures to secure an ash content much below seven per cent., as he would secure no premium on coal for a lower ash content, but it was all important that he should secure for all his coal a uniform ash of approximately seven per cent.

Newell G. Alford, *Chairman*: Is the fusing point of the ash modified by removal of refuse—that is, does the removal of refuse affect the fusing point of the ash?

Col. Warren R. Roberts: I think it would depend very largely on the character of the refuse removed as to what effect its removal would have on the fusing point of the ash. However, I think some of the engineers present could likely answer this question for you.

P. R. HORD:* I do not know that I have a great deal to say on that. Ash raises trouble with handling coal in the furnace if it is excessive. A low-fusing ash which form clinkers readily is the source of most trouble. Reducing the proportions of refuse in the coal will have a tendency toward reduced clinker formation, which is a decided advantage.

A large proportion of ash in the coal requires that the fire be cleaned oftener. With hand firing this means opening the doors, admitting excess air, and lowering efficiency for several minutes at a time. With a modern stoker the ash can be removed with but little loss, as the time required for this operation is much shorter and is not necessarily accompanied by the opening of doors in the furnace.

High percentage of ash represents that much waste matter which absorbs heat from the coal, and this heat is carried off in the ashes except on stokers that have deep clinker-grinder pits that retain the ash a sufficient time to allow the greater portion of this heat to be given off to the boiler.

*Pittsburgh Manager, American Engineering Co.

EVOLUTION OF COMBUSTION VOLUMES IN DESIGN OF BOILER FURNACES FOR PULVERIZED FUEL*

By H. W. Brooks†

INTRODUCTION

Since the graduation of pulverized fuel for boiler firing from the experimental stage to its present pre-eminent position of accepted operating dependability which caused Governor Pinchot's Giant Power Survey Board to speak of it as "the most efficient known method of generating power in very large quantities," probably the most discussed single problem of its application has been that of "large" combustion volumes.

The new art was both fortunate and unfortunate in being commercially developed at a time when engineering knowledge was making rapid strides toward a new and increased understanding that marked reductions in combustion losses could be obtained by the adoption of more liberally designed furnaces. The increased boiler ratings demanded in modern power-station practice had also increased the necessity for larger furnaces to permit higher combustion rates without excessive hydrocarbon losses, to prevent smoke, and to reduce maintenance costs.

Pulverized fuel, then, was fortunate that it might aid in applying this new knowledge to more efficient steam-generating practice, but unfortunate in that, being new (at least to boiler-furnace operators) and hence the major topic of discussion among power-plant engineers, it suddenly found saddled upon it the onus of necessitating vastly increased costs of boiler-house building as a characteristic inherent to pulverized-fuel firing alone, against which its admitted advantages must be weighed. Many station designers therefore credited pulverized fuel with the decreased annual coal bill which careful operating tests uniformly demonstrated, but debited this saving by the difference between the fixed charges on a small old-fashioned stoker plant and the modern up-to-date, pulverized-fuel design.

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COMBUSTION VOLUMES FOR STOKER FURNACES

Engineers generally failed to recognize that it was primarily through research in stoker-fired plants that the need for, and the data on, larger furnace volumes had been developed. For instance, for a Murphy stoker tested[1]* by the United States Bureau of Mines in 1914, the following table of volumes had been deduced as an example with a furnace running with 50 per cent. excess air (corresponding to 12.4 per cent. CO_2 in the flue-gas) and combustible content of the flue-gas not to exceed 0.2 per cent.

Coal per square foot per hour Pounds	Volume of combustion space Cubic feet	Ratio of combustion volume to grate area	British thermal units per cubic foot of combustion volume
20.9	58	2.3	4980
28.4	73	2.9	5100
44.3	75	3.0	7760
58.4	88	3.5	9200

The values in the fourth column are the author's slide-rule computations from the coal (13,811 B.t.u.) described on page 20 of Technical Paper 63 of the United States Bureau of Mines.

That anything like the combustion volume of one cubic foot per 5000 to 10,000 B.t.u. heat release in the furnace should be required for complete combustion in a stoker-fired furnace was startling, to say the least, to the furnace designer of the day who was accustomed to compute his volumes at from 70,000 to 100,000 B.t.u. per cubic foot. Subsequently many commercial installations of high-set boilers over stoker-fired furnaces were made and tested. It was found that the furnace proportions necessary to obtain complete combustion with a proper amount of air were too large to justify economically the results obtained. Beyond a certain limit, the combustion gains were too small to warrant the additional investment. As commercial features must always govern, stoker furnaces were subsequently designed with the knowledge that complete combustion would not occur therein, just as boilers were designed with the knowledge that some heat would pass up the chimney.

Gradually, a rule-of-thumb formula for stoker furnace design which became much used was "two cubic feet of furnace per horse-

*See references at end of paper.

power developed."[2] This was rather indefinite, however, due to the great variation in coal per horse-power obtainable from various fuels, so that eventually there has developed the modern rule, for stoker furnaces in central-station practice, of one cubic foot of effective volume for each 18,000 to 24,000 B.t.u.[2] liberated per hour. Between these figures, the efficiencies, capacities, and maintenance obtainable justify the designs on the basis of modern costs and fuel prices. Most existing stoker furnaces are only about one-fourth of this size. Naturally their efficiencies are low, their capacities limited, and smoke almost inevitable. The recent recommendations as given by the Stoker Manufacturers' Association for setting heights of various types of boilers equipped with stokers (designed primarily for industrial-plant practice at 125 to 175 per cent. of rating rather than central-station practice at 250 to 500 per cent.) figure out somewhere near the maximum of the range above mentioned.

Table I is from a table compiled in 1923 by E. B. Ricketts.[3] It is shown for the purpose of indicating modern tendencies in design of central-station, stoker-fired installations as compared with older practice.

TABLE I. CUBIC FEET OF FURNACE VOLUME PER RATED HORSE-POWER (10 SQUARE FEET BOILER HEATING SURFACE)

Recent stations	Chain-grate stokers	Underfeed stokers
American Sugar (Baltimore)	2.00	....
Kansas City	2.57	....
Dalmarnock (Glasgow)	3.10	....
Barking (London)	3.87	....
Calumet	4.45	....
Waukegan	5.75	....
Dodge Brothers	....	2.17
Seward	....	3.24
Colfax	....	3.45
Springdale	....	3.95
Hell Gate	....	4.23
Gennevilliers (Paris)	....	4.50
South Meadow	....	4.56
Delaware	....	4.80

Older stations	Chain-grate stokers	Underfeed stokers
Waterside	....	1.05
Essex	....	1.95
Muscle Shoals	....	2.19
L Street	....	2.43
Connors Creek	....	2.72

Contrast the 1.05 cubic feet per rated horse-power of the older Waterside with the 5.75 cubic feet of the Waukegan chain-grate installation, and the 4.80 cubic feet per rated horse-power of the Delaware station underfeed installation.

FURNACE COMBUSTION VOLUMES WITH PULVERIZED FUEL

Realizing that coal in a finely divided state after pulverizing had less work to do in disintegrating under the influence of heat than coal in lumps, the designer of pulverized-fuel furnaces, by experiment, early determined the figure of approximately 25,000 to 27,500 B.t.u. per cubic foot as a practicable limitation of heat release for direct jet firing. This was immediately compared with the 70,000 to 100,000 of the old inefficient stoker-fired setting of limited capacity; and, pulverized fuel being new and much in the public eye while the more familiar stoker firing was commonplace and presumably well known from long association, a howl arose to high heaven that the "large" combustion volumes required for pulverized-fuel furnaces made increased fixed charges so high as almost to wipe out the economies of the method. Exponents of pulverized fuel did but little to defend themselves against this unjust accusation. First, they realized that stoker operators who did not take advantage of the latest developments in their own art would inevitably be forced by competition to install new fuel-burning equipment which more than likely would prove to be pulverized fuel. Second, a few pulverized-fuel engineers themselves vaguely realized that they had not yet taken as complete advantage of the inherent possibilities of their method as they might. They knew it took a one-inch coal cube from 10 to 25 minutes or more to burn, while the multiplied surface exposure of a pulverized-fuel particle made it a matter of but 0.2 to 0.8 seconds, depending on the chemical and physical composition of the coal, its fineness, excess air supply, mixing, and turbulence of flow. Why, then, should they

require furnace volumes but 19 per cent. $\left[1 - \frac{21,000}{26,000}\right]$ less than the stoker man? Why should they not anticipate volumes of but a small fraction of those of the stoker furnace? True, in the latter there was much more coal, slowly burning on the grate at a given time. But why was it not possible similarly to force in more pulverized fuel and burn it in its finely divided state before it reached the boiler tubes?

It was also true that with the known methods of firing, the refractory service conditions were apparently more difficult, but as the flame temperatures with pulverized fuel were but little higher than the maxima within modern super-stoker-fired fuel beds; and, as actual flame erosion could be controlled by directing the jet in such manner as not to impinge directly upon the walls, it looked as though the only explanation was that the stoker man was putting his radiant heat where it belonged (in the tubes) while some pulverized-fuel men, at least, were permitting it to be dissipated uselessly against furnace walls and thus contributing to their destruction.

One writer stated that the "large" furnace volume was required "because of the methods of introduction of air for combustion and the 'lazy' nature of the flame developed by such methods"; and so the discussion waged merrily on, pulverized-fuel exponents, each with varying degrees of success, endeavoring to explain the situation by his own theory. As Mark Twain said about the weather, much was said but little done about it. Even to-day it is curious in searching technical literature to note the scarcity of specific information available on this much needed subject. The literature contains literally hundreds of furnace lay-outs and sketches, many of them quoting furnace dimensions and volumes. The *reasons* for these particular dimensions and proportions were left to the reader's imagination and ingenuity.

Like a lamp filament under the influence of increasing voltage, the early stages of discussion of combustion volume developed much heat but little light. When, however, the voltage of economic necessity gave birth to the necessary inventive urge, the light burst forth as speedily as in the lamp of the analogy when increasing voltage produces the incandescent stage. To-day, after experiments of several years and an operating-scale test of more than a year, it is possible, for

the first time, to announce to the engineering public that the problem of combustion volumes in pulverized-fuel furnaces has been solved.

FUNDAMENTALS OF PULVERIZED-FUEL COMBUSTION

In order to gain a clear conception of the fundamental conditions covering the problem, let us visualize for the moment the progress of a pulverized-coal particle from the mouth of the feeder nozzle through the stages of ignition and flame propagation to the stage of complete combustion, and subsequent cooling upon its arrival at the boiler tubes. Present engineering practice in fineness of central-system bituminous pulverization ranges from 60 to 70 per cent. passing through a 200-mesh screen. The size of screen opening of 200-mesh screen (Institution of Mining and Metallurgy series) is 63 microns (0.063 mm.) square, while that of 150-mesh screen is 84 microns square. For convenience in calculations, therefore, let us assume the average size of particle to be a 70-micron cube. This means that in one cubic centimeter there would be contained 2,900,000 coal particles. As a matter of fact, there are actually, according to microscopic count, from 10 to 20 times this number of particles (depending upon the coal) in coal pulverized in a screen mill, and about 5 to 10 times this number in that pulverized in an air mill. This is on account of the high percentage of impalpable dust content many times finer than 200 mesh. The differences between the two methods of pulverizing is best illustrated by the photo-micrographs reproduced in Fig. 1 and 2, the former of which represents pulverized coal from an air mill, while the latter represents that from a screen mill.

According to the Smithsonian Institution there are, at 760 mm. of mercury and zero C., in a cubic centimeter of any gas, including air, 27 million billions of gas molecules, the oxygen atom having a radius of three-billionths of a centimeter. Dividing the number of oxygen atoms per cubic centimeter by the number of 70-micron coal cubes per cubic centimeter, we find that each average coal particle must split up into 9,300,000,000,000 carbon atoms, and each must locate its corresponding oxygen molecule. Such figures obviously mean little to us. Let us, therefore, multiply the size so that we may better visualize the process. The airship *Los Angeles* is 650 feet long, and has a total volume of 2,700,000 cubic feet. Let us consider the

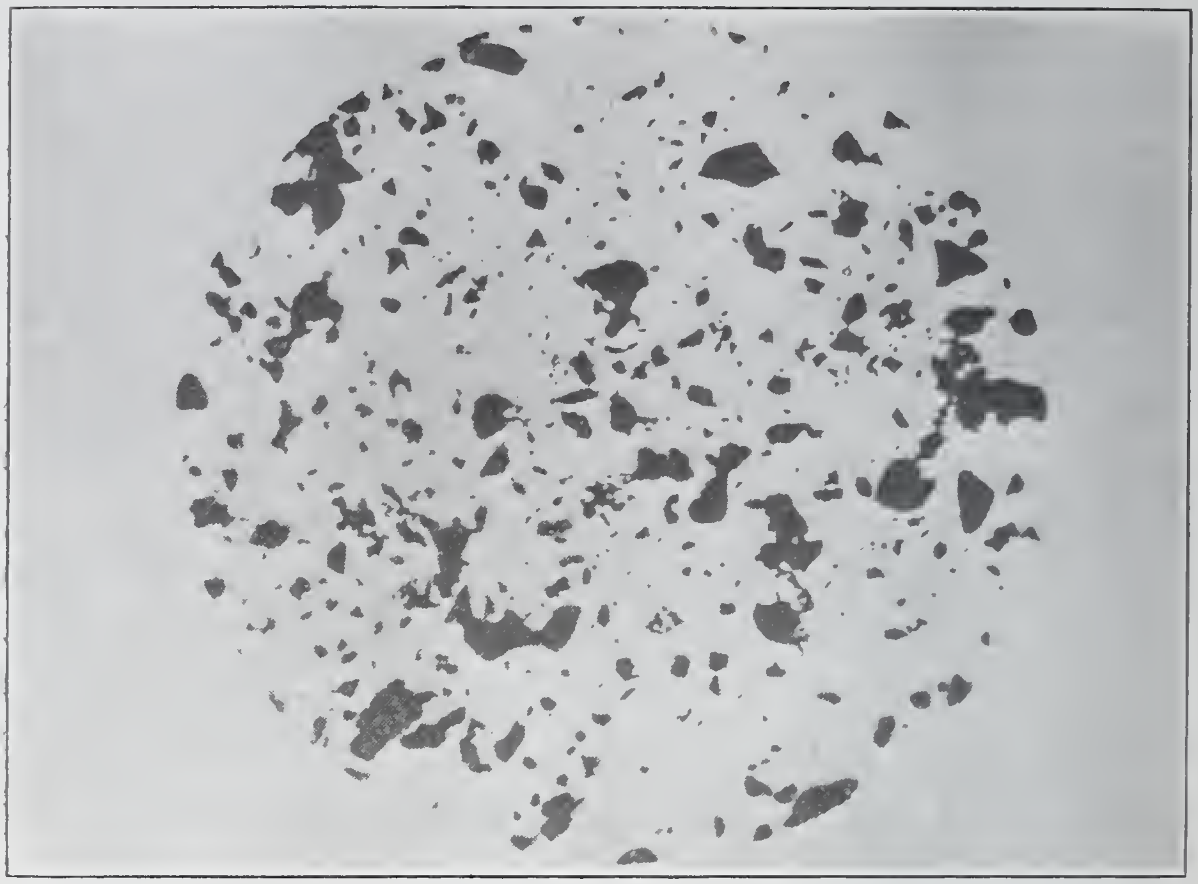

Fig. 1. Coal from Air Mill. Fineness of 300 Mesh. × 300.

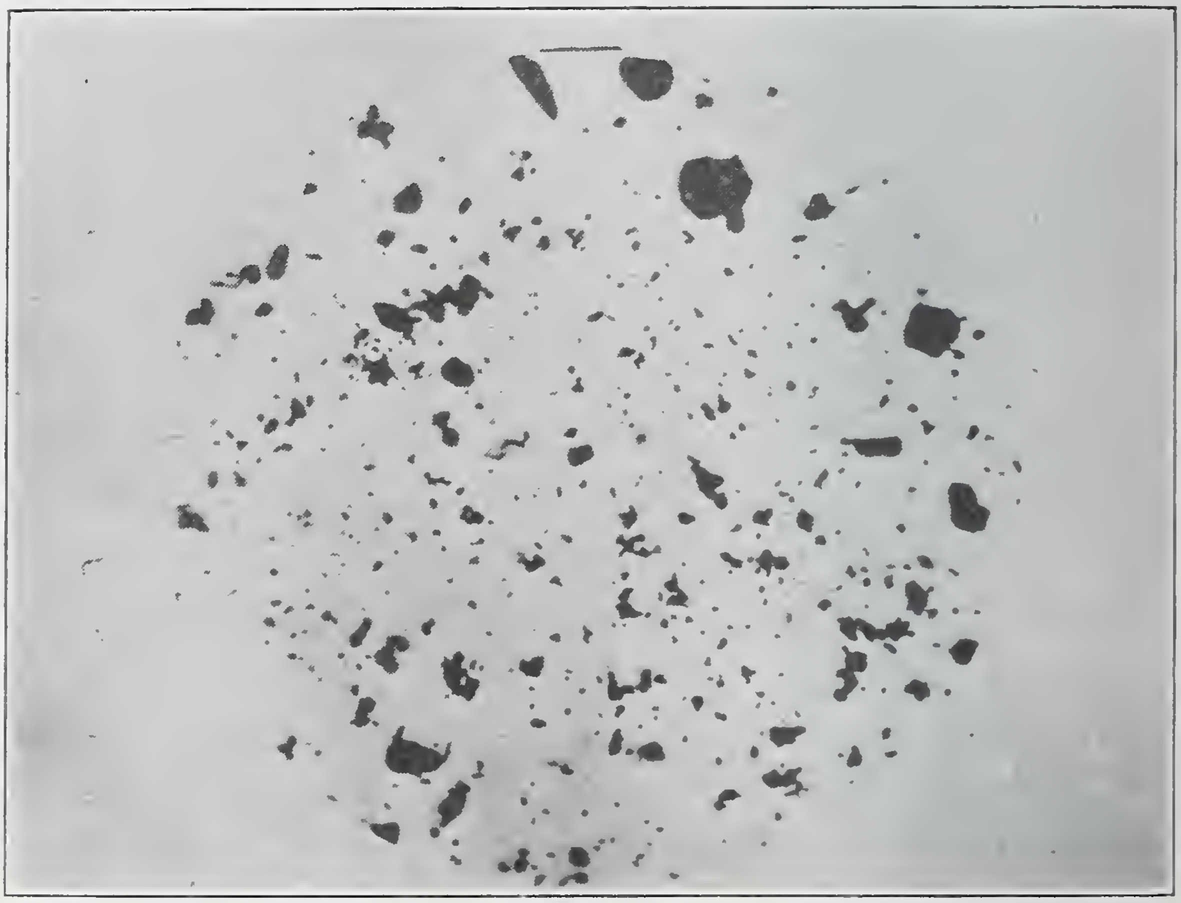

Fig. 2. Coal from Screen Mill. Fineness of 300 Mesh. × 300.

carbon particle as a balloon the size of the airship *Los Angeles*. The comparative size of the oxygen atom would then be that of a cube somewhat less than 0.08 inch on a side; or, let us say, about the size of a gnat.

Picture then the *Los Angeles*, representing the coal particle, moving through the air either horizontally at a rate of somewhat less than a mile a minute, or vertically at somewhat more than a mile a minute, carrying entrained along with it at approximately the same speed some 12,000,000,000,000 gnats, representing the oxygen atoms. (For simplicity it is assumed that all air is introduced as primary air, including 30 per cent. excess.) These oxygen gnats, in addition to their lineal speed, are vibrating in fixed orbits at velocities many times the speed of a bullet and measured in miles per second. Complete combustion necessitates the larger coal particle (typified by the airship) disintegrating into some 9,300,000,000,000 pieces and combining with a corresponding number of oxygen molecules. Heat is the agency through which this disintegration is accomplished. In stoker firing with pieces of coal millions of times the size of our pulverized-coal particle, we aid this disintegration but little, leaving nature to take its course. In pulverizing coal, we assisted the natural processes somewhat by reducing the size of the particle before firing. We at least *began* to appreciate the huge task a piece of coal assumed in disintegration, though we did not materially aid the actual process of diffusion and atomic attraction which brought the carbon atom and oxygen molecule together. Realing this, many writers on combustion stressed the importance of turbulent flow, agitation, and mixing, to aid the natural diffusivity, but a practical means of accomplishing this mixing both prior to and subsequent to ignition has heretofore remained undiscovered.

If the coal particle were suspended in still air with conditions of temperature and pressure suitable, and gravity had no effect on it, its combustion would proceed in a very imperfect manner. It would begin upon the whole surface, but the carbon would be immediately isolated from the air by a layer of ash and burning gas from which it could not escape because gravity is assumed to have no effect and the air is perfectly still. The combustion, therefore, would stop. The same effect arises if a coal particle be carried in a current of air at precisely the same velocity as the air itself, no matter what that

velocity may be. In order that combustion may continue, it is necessary that there shall be relative movement between the air and the carbon. In pulverized-fuel firing this is effected by obstacles in the path of burning gases, by changes of volume and pressure in the flame jet at different points, and by the difference of pressure or velocity produced either naturally or artificially by turbulence or agitation. Just how to accomplish this relative movement practically with optimum results and without excessive refractory cost has been the great problem of pulverized-fuel firing.

Let us now continue to follow through the progress of the coal particle as it passes through the furnace. Please bear in mind when considering the phenomena described below that according to the experiments of Audibert[4] this whole process of combustion is completed within 0.2 to 0.6 of a second for a particle of the size discussed, depending on the kind of coal, excess of air, etc. Hurled into the furnace, entrained in the air jet from the burner nozzle, the influence of the radiation from the flame and from the furnace walls first begins to drive off the surface moisture in case this has not previously been done by a drier. Next, the cellular moisture embedded within the coal structure itself commences to be driven off and turned into steam. Both of these processes, if not previously performed in a drier, serve to cool the surroundings of the coal particle and hence delay the ignition, thus unduly extending the flame length and so serving to increase necessary combustion volume. First the impalpable fines, then the coarser particles of the coal, then begin to undergo destructive distillation accompanied by the swelling of the coal particle, and its fusing into a hard crust (if a coking bituminous coal), or its splitting up or crumbling into thousands of small particles (if an anthracite, non-coking bituminous or lignite). Each new surface thus exposed provides an additional fertile field for the attack of the hot oxygen molecules.

This stage of combustion has been aptly designated by Bone[5] as the "preflame period," during which the combustible and air must be brought into certain thermal condition before the rate of combustion of the reactive constituents is sufficient to cause the chemical change to become autogenous or self-propellent—a condition which must always be fulfilled before flame can appear. As soon, however, as the

rate of combustion becomes such that the mixture "self heats," its temperature will very rapidly rise to the point at which flame appears.

Combustible gases, pitch, tar, naphtha, etc., begin to be driven off from about 700 degrees F., and this continues until the fuel is at a temperature of about 1800 degrees F., when practically all are driven off. The heavier constituents will not burn as tar, pitch, etc., but must be heated until they pass into a gaseous state, and, unless conditions are favorable for their smokeless combustion, in burning will make dense black smoke, consisting of water vapor and the gaseous products of combustion, colored with fine particles of carbon or soot and with the unburned vapors of the tarry constituents of the fuel. In the smokeless combustion of fuel, five factors enter—the air supply, the intermixture of the volatile matter and the air, the temperature in the combustion chamber, the chemical and physical characteristics of the fuel, and the time allowed the volatile matter in which to burn before it actually strikes the boiler. The gases produced consist chiefly of hydrocarbons (methane, with smaller proportions of ethylene, benzine, and probably also ethane, hydrogen and carbon monoxid), while the tarry vapors are mixed with a certain proportion of finely divided carbon (soot). Meanwhile, the actual ignition of the carbon of the coal particle has begun to take place, first in the finely divided impalpable dust and subsequently in the coarse particles, in some of which combustion probably continues until the end of the flame travel. The ignition temperature of a given combustible mixture may be defined as that degree to which it must be raised, at least locally, in order that the chemical action becomes autogenous.

The generally accepted theory in America is that the first stage of burning is in the oxidizing zone where carbon dioxid is directly formed from the carbon. This carbon dioxid left in contact with hot carbon turns to carbon monoxid in a reducing zone at a rate increasing with the temperature, area, velocity of gas flow, and time of contact. Thus, during the first stages of coke combustion, the American theory would be that carbon dioxid was formed originally and thereafter carbon monoxid produced at the expense of carbon dioxid, until the entire combustion had been completed, the process being

$$C \rightarrow CO_2 \rightarrow CO \rightarrow CO_2.$$

Contrary to our view, the European theory[5] is that both carbon

dioxid and carbon monoxid are produced simultaneously as a result of the decomposition of the complex substance C_xO_y, which, according to this theory, is both an important and an initial product of the action of oxygen upon carbon. This process would be represented by

$$C \longrightarrow C_xO_y \begin{array}{c} \nearrow \; CO \; \searrow \\ \searrow \; CO_2 \; \nearrow \end{array} CO_2.$$

This theory reconciles a good many established facts which would otherwise appear conflicting, and seems to be a more probable action in a pulverized-fuel furnace.

As to the order of these reactions and their speed in the furnace, Henry Fayol found, "as might be anticipated, that the finer the state of division of a coal, the more rapidly does it combine with oxygen and catch fire." Regarding its subsequent combustion, Audibert[4] makes the following statement:

> The duration of combustion diminishes with increased fineness of pulverization; this diminution is variable, depending upon the character of the combustible. One may in general characterize this by saying that, other things being equal, the duration of combustion of a powder passing through 120 mesh and over 140 mesh will be about two to three times that necessary for a powder of the same nature passing through 220 mesh and over 240 mesh.

His curves, given in Fig. 3, illustrate for coals and semi-cokes the relative combustion duration at these two degrees of fineness.

Burton[6] gives as the approximate ignition temperatures for various kinds of coals the following:

Anthracite	925 degrees F.
Semi-bituminous	870 degrees F.
Bituminous	766 degrees F.
Coke	red heat

It is the fixed carbon which burns at these temperatures, but the escaping gases will not ignite in air except at much higher temperatures as given (approximately) by H. B. Dixon and H. F. Coward,[7] as follows:

Gases	Ignition range Degrees F.
Acetylene	760 to 820
Propane	900 to 1050
Ethylene	1000 to 1015
Hydrogen	1075 to 1095
Ethane	1100 to 1300
Carbon monoxid (moist)	1190 to 1220
Methane	1200 to 1380

The volatile combustible constituents thus evolved under the influence of radiated heat during the early stages of the passage of the particle into the furnace will amount in all to between 20 and 50 per cent. of the weight of the ash-free coal charged. While one pound of fixed carbon will generate only about 14,600 B.t.u., a pound of these gases will generate about 23,500 B.t.u., so that their contribution to furnace efficiency is greater by far than their proportionate weight would indicate. At temperatures below their ignition points, their combustion is very slow, and, therefore, if not properly exposed to temperatures above these they pass off unburned and wasted.

In stoker-fired furnaces, the oxygen needed for the combustion of these gases must be supplied as secondary air, for it has been proved as a result of tests by the United States Bureau of Mines upon a six-inch fuel bed that the atmospheric oxygen drawn in through the grate was all used up within the lower 3½ or 4 inches of the fire. The zone of highest temperature, 2500 to 2800 degrees F., according to the draft, was found to be usually about three to five inches above the grate, and the combustion of the gases in it was practically independent of the rate at which the air was drawn or forced through the fuel bed, the increase in the draft merely increasing the rate at which the carbon of the coke was gasified, and raising the maximum temperature of the bed. Thus, if the secondary air supply was improperly adjusted to meet the varying load conditions, or not thoroughly mixed—or with poor furnace construction, careless firing, poor draft or other control or mechanical difficulties—these gases were so difficult to burn in stoker-fired furnaces that their heat value was often wasted.

With pulverized fuel, however, the air having more intimately mixed with the coal particles, could either be supplied entirely as

primary air, or partly as primary and partly as secondary, depending upon the needs of the operation, the desire of the designer and the will of the operator. In boiler furnaces the aim was to secure that combination of primary and secondary air which would inhibit the

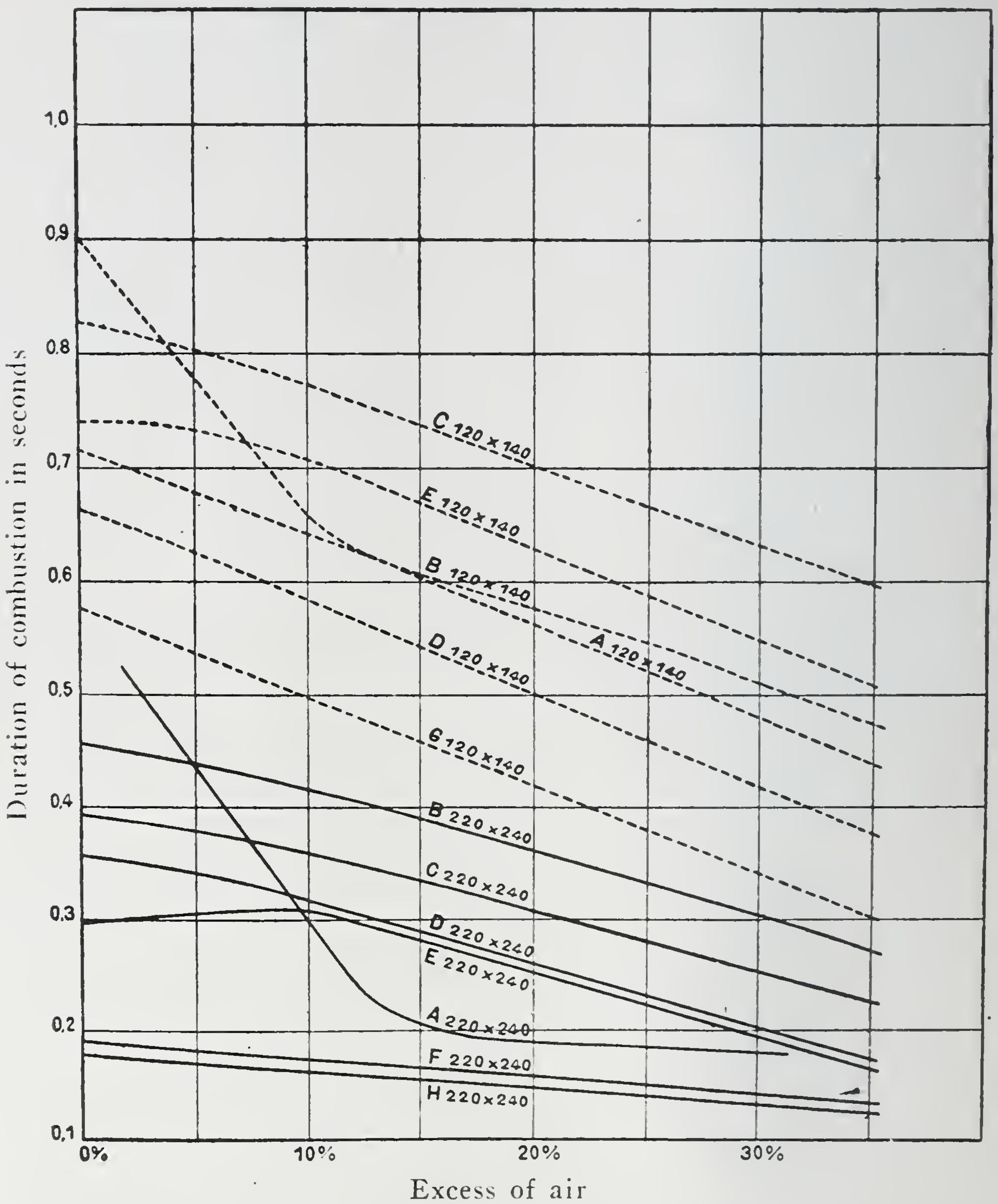

Fig. 3. Duration of Combustion with Coals of Different Degrees of Fineness with Varying Primary Excess Air.

production of the well known development of smoke flames in the furnace with a minimum of combustion volume consistent with both efficiency and furnace maintenance. The principal object for the introduction of secondary air was in lieu of a better device for mixing

the air and the coal particles. Combustion engineers realized that with jets fired vertically downward the secondary air jets intermingled with the primary fuel and the air only to a certain extent in the initial stages, and that there was a tendency towards stratification, and hence delayed ignition until the flame began to decrease in velocity through expansion. An attempt to inject low-velocity air streams into the high-velocity primary jet results in an effect more or less analogous to blowing air from the mouth directly against and at right angles to the flame of a blow-torch. Such action could hardly be expected to decrease flame lengths materially. This delay in ignition rate would of necessity force long flame travel, and hence high combustion volumes.

PAST AND PRESENT METHODS OF PULVERIZED-FUEL FIRING

One of the first efforts to build a commercial, pulverized-fuel, boiler furnace resulted in the well-known Bettington design, in which all of the air was introduced as primary air, the jet of coal and air projecting vertically upward and thus being assisted by the stack draft. Both the introduction of all the air as primary air, and the assistance of the jet velocity by the stack draft, were quite in accordance with the fundamental principles of combustion. As is well known, however, mechanical difficulties were encountered, resulting in the clogging up of the nozzle and to a large extent the abandonment of this design. Many combinations were tried out thereafter, but, when the first large-scale operating installations were made, it was decided to use the system of firing vertically downward (See Fig. 4), opposing the stack draft during the first stages of the flow. This practice obviously necessitated a higher jet velocity than was necessary on the Bettington design. Thus jet velocities about double those used by Bettington were employed, velocities approximating 6000 feet a minute being adopted as the lowest which would carry the necessary amount of coal into the furnace against the stack draft at the maximum rating which it was desired to carry. This resulted in a maximum or terminal velocity, of the vertical coal and air jet, of about 60 feet a second within the furnace. About 15 to 30 per cent. of the air was introduced as primary air with the incoming coal, the balance being shot horizontally towards and into the downwardly

vertical flame. Thus it was hoped to secure somewhat better mixing and lesser flame lengths.

The resultant effect is thus described in a Bureau of Mines bulletin[8] in which tests of such a method are reported:

> (1) The speed of flame propagation through this mixture depends on the ratio of coal to air and if this speed is to be kept as high as possible, the mixture must contain *considerably less air* than is required to burn it properly. Accordingly to keep the rate of flame propagation high it is necessary that *only a part of the air* for combustion be admitted with the coal at the burners and the remainder admitted later. This device has the additional advantage of facilitating the mixing of the particles of coal, combustible gases and air more thoroughly than the admission of all the air with the coal. It is carried out in this furnace by admitting first of all, through the central burner pipe, equal masses of coal and air, with a downward velocity of 50 to 60 feet per second.
>
> (2) On the outside of the nozzles, an additional mass of air equal to twice that of the coal, enters downward at about 10 feet per second. Thus the relative velocity of these streams is about 40 to 50 feet per second.
>
> (3) The remaining air with about 8 times that of the mass of coal, passes horizontally through the front wall openings at a velocity of 10 to 20 feet per second and impinges on the flame. Thus the final supply of air moves in a direction nearly at right angles to that of the downward stream of coal and surrounding gases and mixes with it rapidly.
>
> (4) Another factor that assists combustion is the weight of the coal, for its weight causes it to move downward at a velocity, relative to the gases surrounding it, which is approximately proportional to the mean linear size of the particle of coal and the square root of its density. Thus the larger particles of coal fall with a greater velocity, rise with a smaller velocity and rub against the surrounding gases at a greater rate than the smaller particles of the same density.

Let us discuss these theories as numbered serially above. (1) As a result of actual tests, Audibert[4] found that exactly the reverse of the condition described was true. His curves of the duration of combustion with different coals of different degrees of fineness are shown in Fig. 3, from which it will be noted that the higher the air excess the shorter the duration of combustion. (2) There will undoubtedly occur to some extent the condition described, though those familiar with the air stratification along the walls of chain-grate, stoker-fired furnaces will wonder how thorough may be the mixing caused by such entrainment around the jet, and whether the cold air so introduced may not surround the jet as stratified walls or blankets of air,

insulating it from the radiant heat from the walls. It should also be noted in this connection that tar run in a stream into air of 1800 degrees F. burns quickly and without smoke, whereas the same arrangement with cold air produces much soot in the form of dense

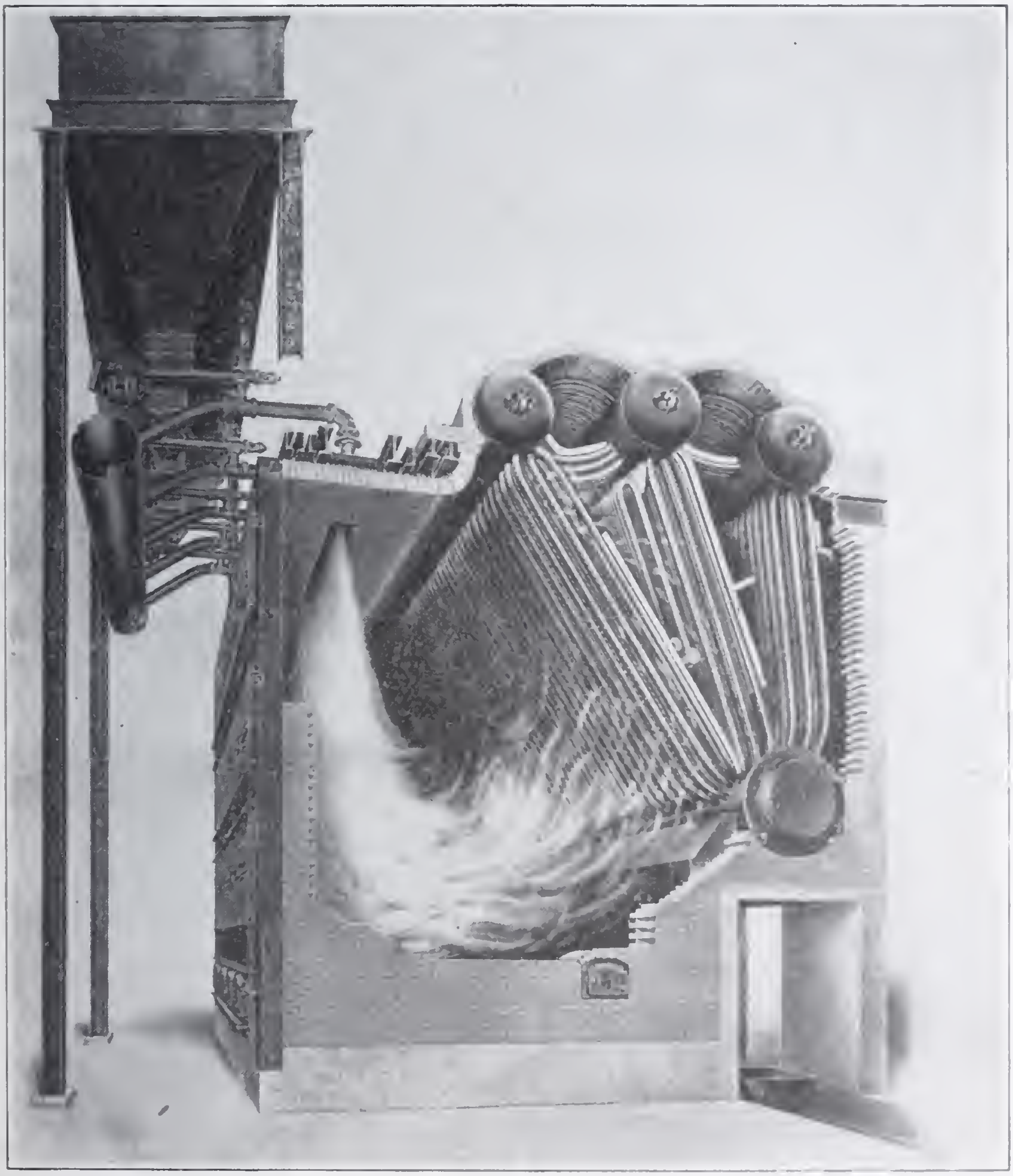

Fig. 4. Method of Firing Vertically Downward.

black smoke, which is exceedingly difficult to ignite subsequently at any temperature encountered in a boiler furnace. (3) The *mixing* of a burning jet of coal and air at 50 to 60 feet per second, with an incoming air jet at right angles at 10 feet per second, would not be

evident to those familiar with stratified gas flow. There might be *some* mixing about the outer edges, but the impinging air could hardly be expected to enter the center or rear portion of the flame. Furthermore, the regulation of the secondary air through this multiplicity of port-holes with varying load is very difficult, this being the principal reason why this design has not been adopted in the cement and metallurgical industries. (4) Undoubtedly this condition is correctly described, and most of the necessary mixing during the first half of the flame travel is probably thus accomplished, at least to the extent to which mixing is possible with this method of firing.

The high velocity, however, at which the incoming jet had to be forced in order to overcome the stack effect, combined with only very partial mixing and combustion during the downward travel, resulted in a very high temperature at or near the bend of the flame, which, combined with the separator action of fuel and slag particles when the jet turned back on itself, resulted in serious slagging trouble on the furnace bottom. The reason for such slagging trouble becomes obvious by reference to Fig. 5, which shows the isothermal lines taken in this furnace on one of the tests. The long, egg-shaped 2600 and 2700 isothermal lines occurring near the bottom of the furnace produced an enormous temperature in the furnace bottom, for the radiant heat absorption of the furnace bottom was of the order of the fourth power of the difference of temperature between the flame and the wall temperature.

With such firing in many cases it was found impossible to run the furnace with low excess air without the ash fusing at the bottom of the furnace. Consequently, subsequent experiments were made with a water coil to cool the furnace bottom. This coil, partly by providing additional radiant heat absorption surface within the furnace, and partly by screening the bottom from the radiation of the flame, kept the bottom temperature below that of the fusion point of the ash, as will be noted by further reference to Fig. 5. It was but natural that on tests to determine the effect of fineness on boiler efficiency with this type of firing, increased coarseness of coal was found to have but little effect on overall efficiency, and that the losses were about the same with the coarse as with the finely pulverized coal. In the language of the authors, "the large pieces of coal may fall to the bottom of the furnace, but they continue to burn until

their combustion is completed." Carrying the same line of reasoning a bit further one might logically expect to dispense entirely with the trouble and expense of pulverizing the coal, instead feeding it in as slack, once a fire had been started on the furnace bottom to serve to ignite the lumps; if he were but satisfied to accept the concentration of

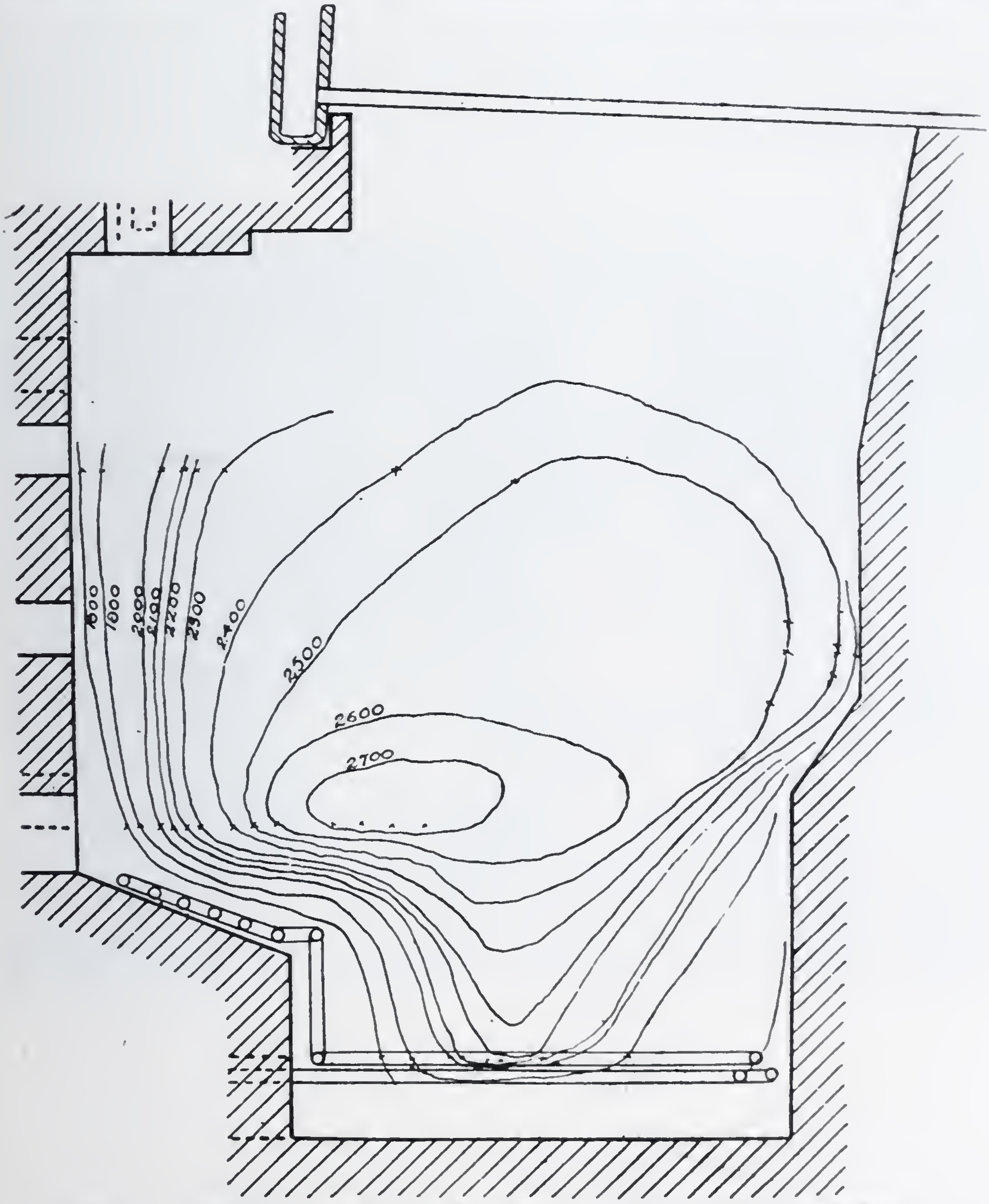

Fig. 5. Isothermal Lines When Firing Vertically Downward.

heat absorption in his water coils and not particularly interested in the absorption of the rest of his boilers; and, indeed, subsequent tests did reveal this high concentration of heat absorption in the water screen, figures of 40,000 to 85,000 B.t.u. per square foot (corresponding to 40 to 85 pounds of water per hour per square foot) being reached.

HORIZONTAL FIRING

Prior even to the Bettington boiler, horizontal firing had been practically the standard for pulverized fuel in the cement and metallurgical industries and had also been adapted with some success by early experimenters in boiler furnace firing (See Fig. 6). With it, the stack draft was not opposed and the velocity of the incoming jet could be cut down to about two-thirds of that necessary with vertical firing, and still carry in suspension the coal necessary for the maximum ratings desired on the boiler. Difficulties with furnace bottoms,

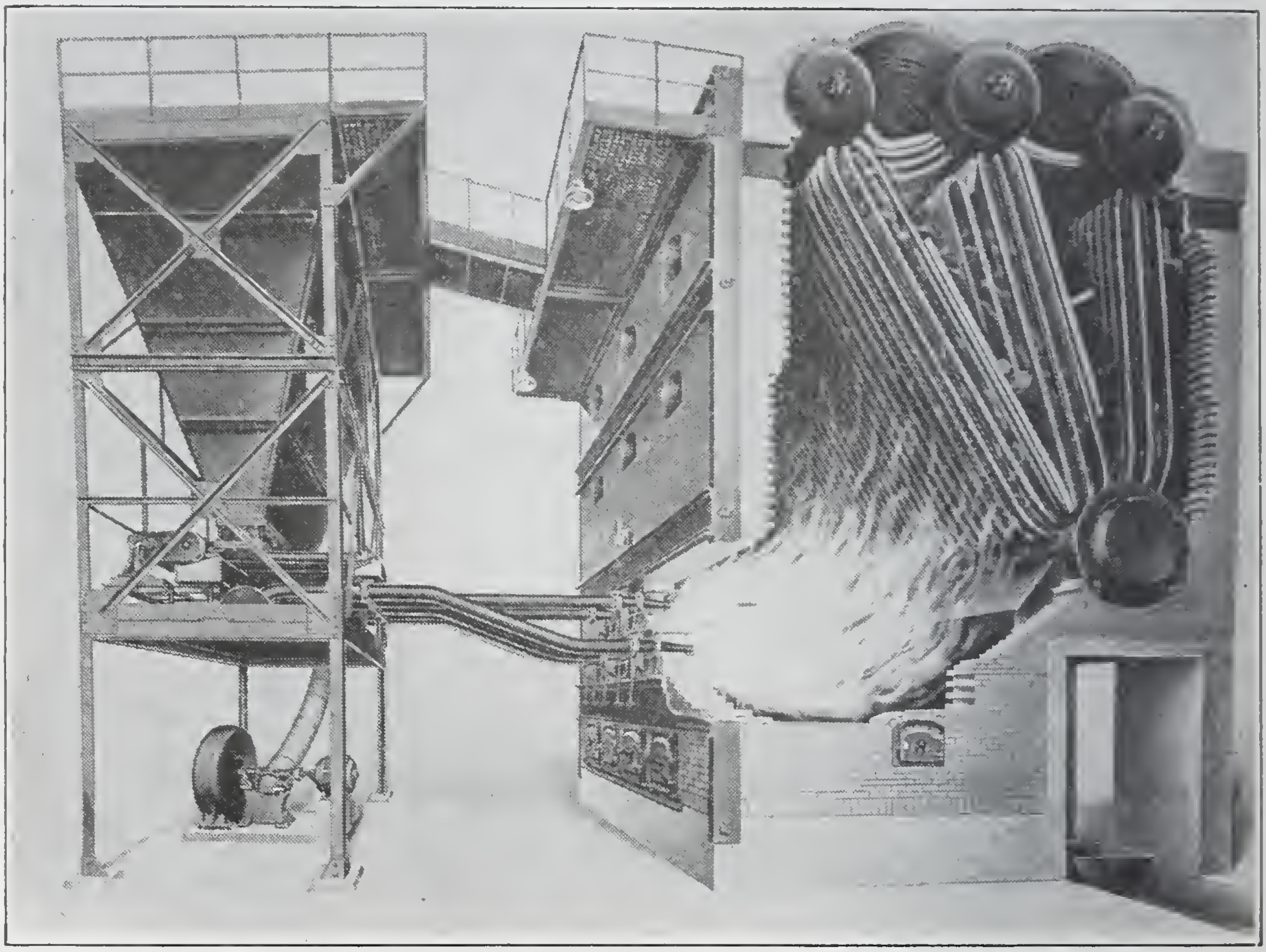

Fig. 6. Method of Firing Horizontally.

as well as long flame travels of vertical firing, thus led to increasing popularity of the horizontal method.

The author's company, except in very special cases, generally recommended splitting up of the large jets into a multiplicity of small jets and the firing of bituminous coal of more than 20 per cent. volatile matter by the horizontal method. The 25 per cent. shorter flame lengths which naturally resulted, with the lesser jet velocities and smaller jets, did apparently eliminate the slagging problem, and

hence obviated the need of the water screen, and materially decreased combustion volumes over those of the vertical method. Furthermore, by turning Fig. 5 at right angles to the horizontal, it will be observed that the long, egg-shaped 2600 and 2700 isothermal areas tilted their axes vertically instead of horizontally, hence radiating their heat, principally to the incoming jet, by way of the vertical furnace walls, which hastened the ignition as well as the flame propagation. Again, the distilling volatiles, instead of being carried along to the bend of the flame travel at the rear of the furnace by the high velocity vertical jets, were through their lighter density released above the horizontal portion of the flame and burned in the gas pocket between the flame jet and the arch. This produced an additional radiant-heat effect close to the point of entry of the jet, which materially aided the heat from the arch in expediting ignition. The secondary air shot in from the rear of the furnace beneath the flame was preheated by radiation, and by reason of its greater density formed an effective cooling air screen which protected the furnace bottom from the radiant heat of the flame, finally being entrained near the burner nozzle at the front of the furnace into the flame. By the method of horizontal firing with coals of greater than 20 per cent. volatile content, therefore, the decrease of combustion volume of the order of 25 per cent. was accomplished and the necessity of water-cooled bottoms eliminated.

One large operator, the Columbia Power Company, successfully combined both vertical and horizontal firing in the same furnace with results superior to anything accomplished prior to that time. Recently, various attempts have been made to adapt to boiler furnaces the so-called "mixing burners," long used with success in the metallurgical industry. Many of these were modified fuel-oil burners. All, or a major portion, of the combustion air was introduced as primary air at relatively low velocities so that the rapid expansion of the gases generally dissipated the turbulent action prior to ignition, permitting stratified flow subsequent thereto when turbulence was most needed. Several of these gave short flame lengths—in fact, often so short as to melt down the front walls. Except in special cases of completely water-cooled furnaces, or where exceptionally wide varieties of coals are utilized, their disadvantages apparently outweigh their advantage, so that to date they have not been widely accepted by boiler-plant

operators in spite of considerable sales effort expended by their proponents.

It was still recognized, however, that there yet remained much to be desired in aiding the speedy and complete combination of the carbon atom with its corresponding oxygen molecule. True, nature had not been forced to take its course to anywhere near the extent necessary with a lump of coal on a stoker; but, as an oxygen molecule and a carbon atom when disintegrated moved in practically a parallel stream flow, there was but little to aid in expediting ignition and flame propagation, with the exception of the natural diffusivity of the gases, the lesser density of the distilled hydrocarbons, and the natural tendency of the coal particle to fly apart under the influence of heat.

The best authorities on pulverized coal well recognized that if agitated or turbulent flow could be accomplished within the furnace the relative speed of the air and the particles of coal would be constantly changing, the film of ash and burned gases charged with distillates would be carried away and new air would reach the particle of coal. It may be observed that the speed of the particle would change with that of the air, but this is true only in part, as the inertia of the particle must be considered; and, moreover, the act of combustion sets up lateral movements of the particle on its own account. It is for this reason that temperature has such an important influence on the activity of combustion. This turbulence of flow constantly serves to modify the conditions of combustion by attacking the dynamic equilibrium which, as a consequence, is able to persist for only relatively short periods. In some remarkable experiments carried out by Audibert[4] in France, certain tests on agitated flow were made in a tube-furnace in which the speed of combustion increased regularly up to the point where an undulatory movement of a frequency compatible with the characteristics of the tube was reached. At that moment the speed of combustion increased much more rapidly. These experiments showed variations in the length of the flame between 15 and 50 per cent. as the air agitations varied between 700 and 2100 a minute; but there was nothing to indicate that 50 per cent. was the maximum reduction, for the frequency of agitation would necessarily vary with the speed of the air charged with coal in the jet, and with many other conditions.

Prof. L. P. Breckenridge, in a study of conditions applying within boiler furnaces,[9] remarked:

> In the discussion of mass action it was stated that mere length of combustion chamber counts for little—that mixing is what counts—and thus there is a possibility of enormously increasing the efficiency of a combustion chamber as a burner of volatile matter. Effort in completing a steam-generating outfit of small dimensions must be largely concerned with the construction of a combustion chamber containing many gas-mixing devices.

Several years ago it occurred to one of the engineers of the Fuller-Lehigh Company that one of the most intense natural manifestations of turbulent flow was in the tornado, where it had been repeatedly demonstrated that materials of considerable tensile strength had actually been torn apart, disintegrated, and sometimes reduced to powder by the intense centrifugal action of the air. Experiments were started at Fullerton, Pa., on a small furnace 18 inches square and 3 feet deep, in which the jets were placed to throw the flame tangent to a tornado of the fire within the furnace; the flame of the first jet being deflected before it reached the refractory walls by the impingement (with equal velocity at right angles) of the flame from the second jet, the third jet again changing the direction 90 degrees, and the fourth jet completing the tornado within the pot. A clearer idea of the placing of these jets in circular and square pot furnaces is shown in Fig. 7 and 8, the latter of which shows connection of the water walls into the circulatory system of the boiler. Fig. 9 shows an actual installation of two well furnaces.

It was well known that the external walls of the ordinary tornado had been observed to be rather sharply defined, and distinct from the surrounding air; and thus it was decided to adapt this principle by placing the pulverized-fuel jets in such relation to the walls that there was little, if any, impingement. As was anticipated, therefore, the refractory portion of the walls between the water-cooling tubes showed little damage due to slagging or erosion, and thermocouple readings taken on the inner surface showed temperatures well within the operating range of ordinary No. 1 fire-brick.

Early during the experiments, the nature of the ignition and combustion taking place in the well proved quite unlike anything experienced engineers had hitherto seen in powdered-coal combustion. The flame itself resembled that of a blow-torch, combustion appar-

ently taking place in a limited zone within the well. By regulating air admission and air pressure it was possible to move the hottest zone into the well itself or to a point just in front of the well. Due to the more efficient transfer of heat by radiant energy caused by higher flame temperatures and lesser *linear* flame velocities, coupled with the intense scouring action of the rapidly whirling gases on the "dead film" surrounding the boiler tubes (known to be the most potent obstacle to efficient heat transfer by convection), the inventor had reason to expect efficiencies higher than had been before demonstrated in pulverized-fuel combustion, as well as a flatter overall performance curve at high ratings.

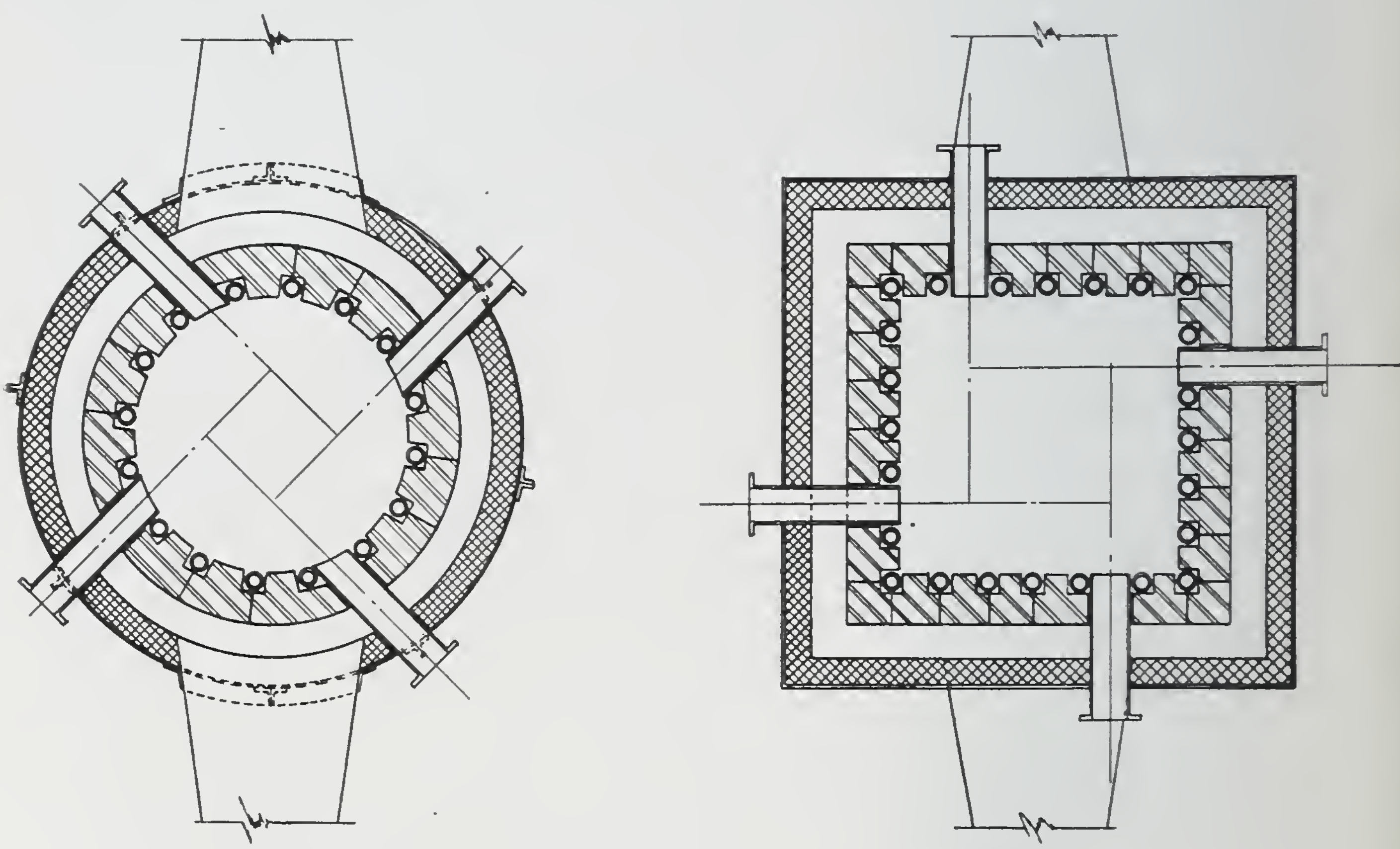

Fig. 7. Plans of Round and Square Wells.

In February 1924 the United Electric Light and Power Company, of New York, undertook a commercial-scale, experimental installation of the new furnace at its Sherman Creek station, where eight other types of pulverized-coal installations were being tried. The efficiencies proved from 2½ to 6 per cent. higher than with the other methods of firing, and the curve of efficiencies at various ratings has been much flatter than anything heretofore demonstrated.

From Fig. 10, showing a recent installation, it will be noted that above the well there is provided a dispersion chamber in which the hot gases, after burning, are allowed to expand before reaching the

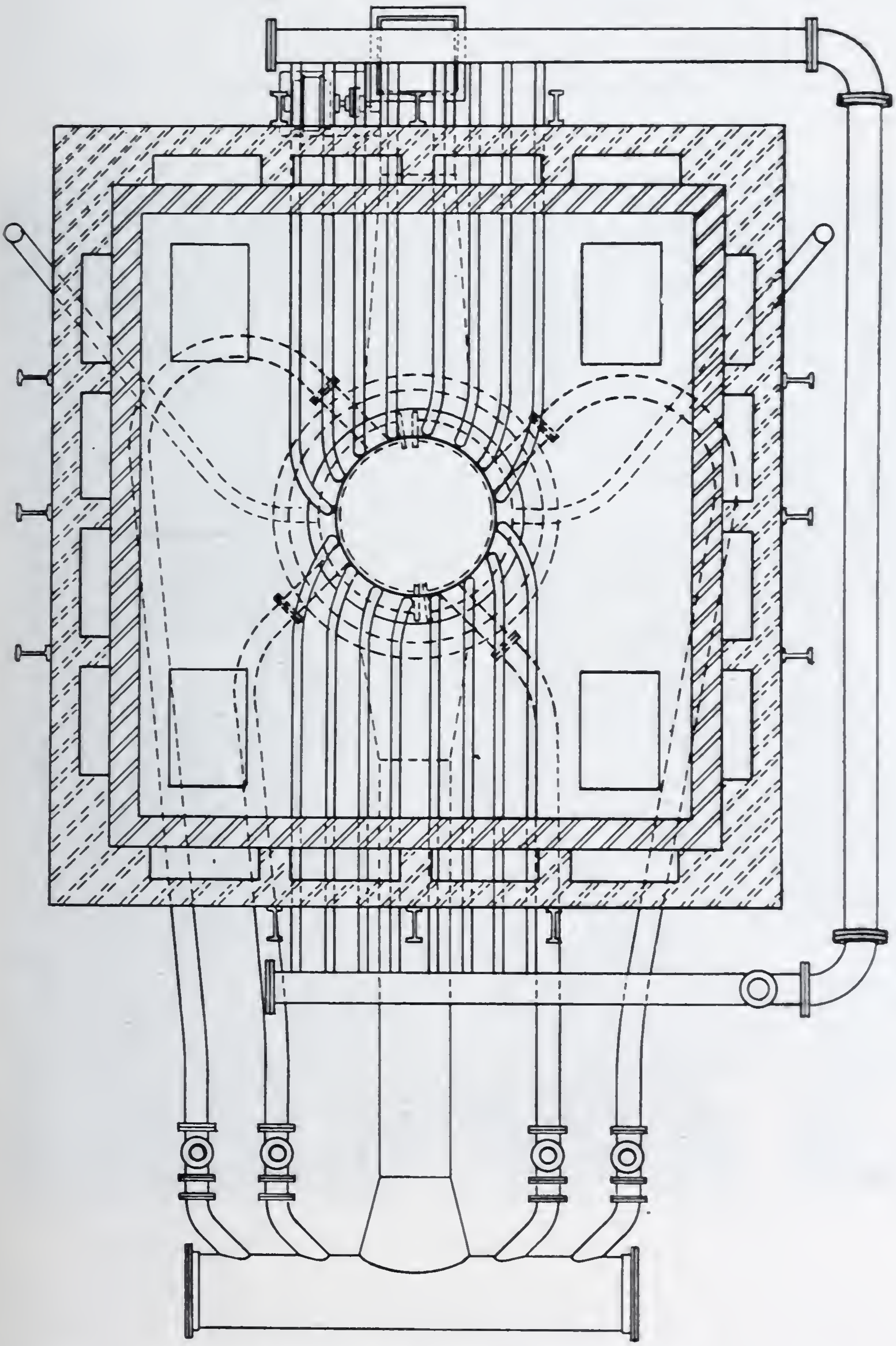

Fig. 8. Well Circulatory System.

boiler tubes. It is not possible to state at this time the minimum size to which this chamber may eventually be reduced. It has definitely been established, however, that the combined volume of the well and dispersion chamber can be made substantially less than the combustion space provided in the ordinary stoker setting.

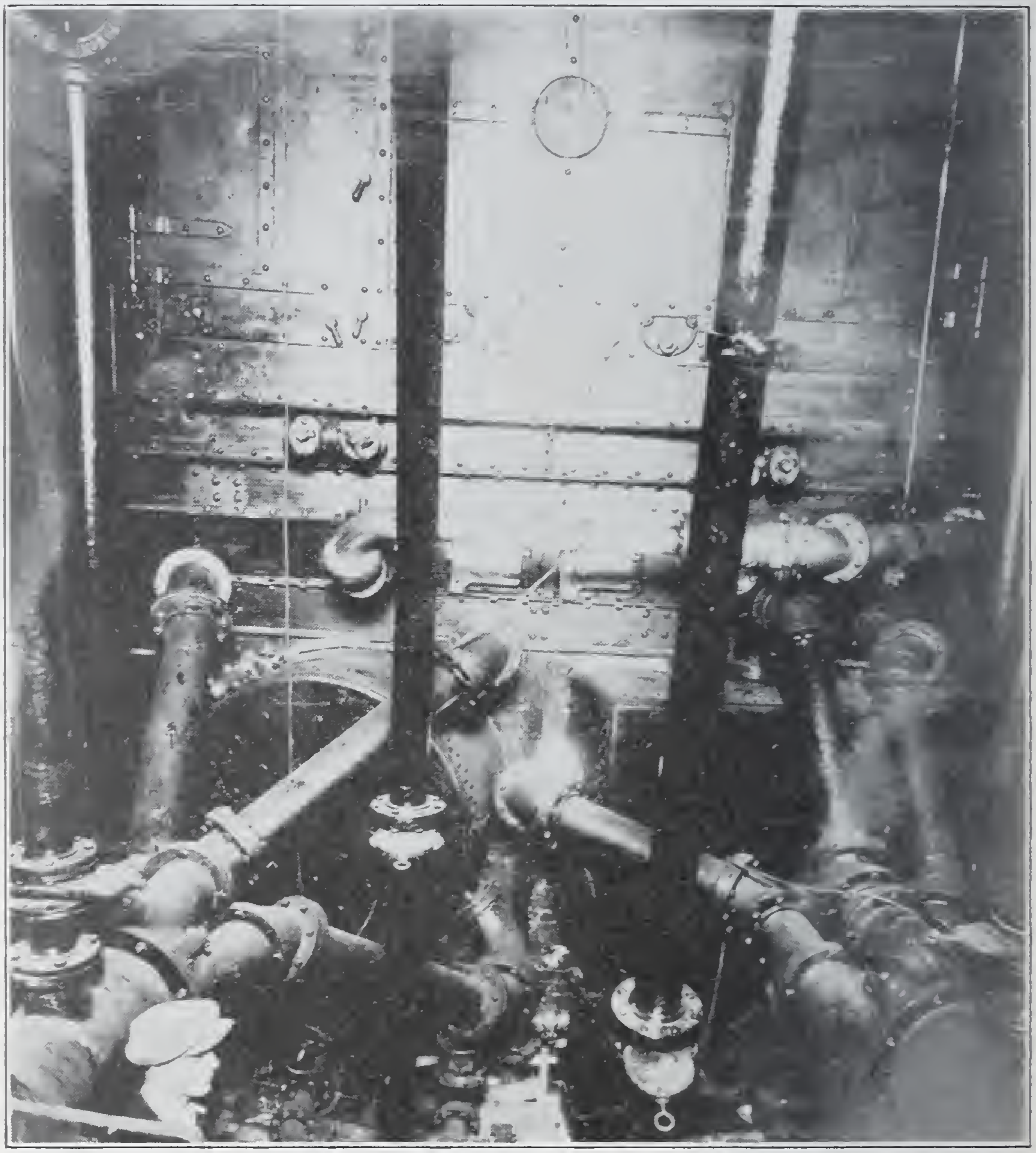

Fig. 9. Installation of Round and Square Well Furnaces.

Fig. 11 shows the rather remarkable phenomenon of the coal equivalent of a 1500-horse-power boiler, at 632 per cent. of rating, being burned in the volume of an eight-foot cube at the experimental plant at Fullerton, Pa.

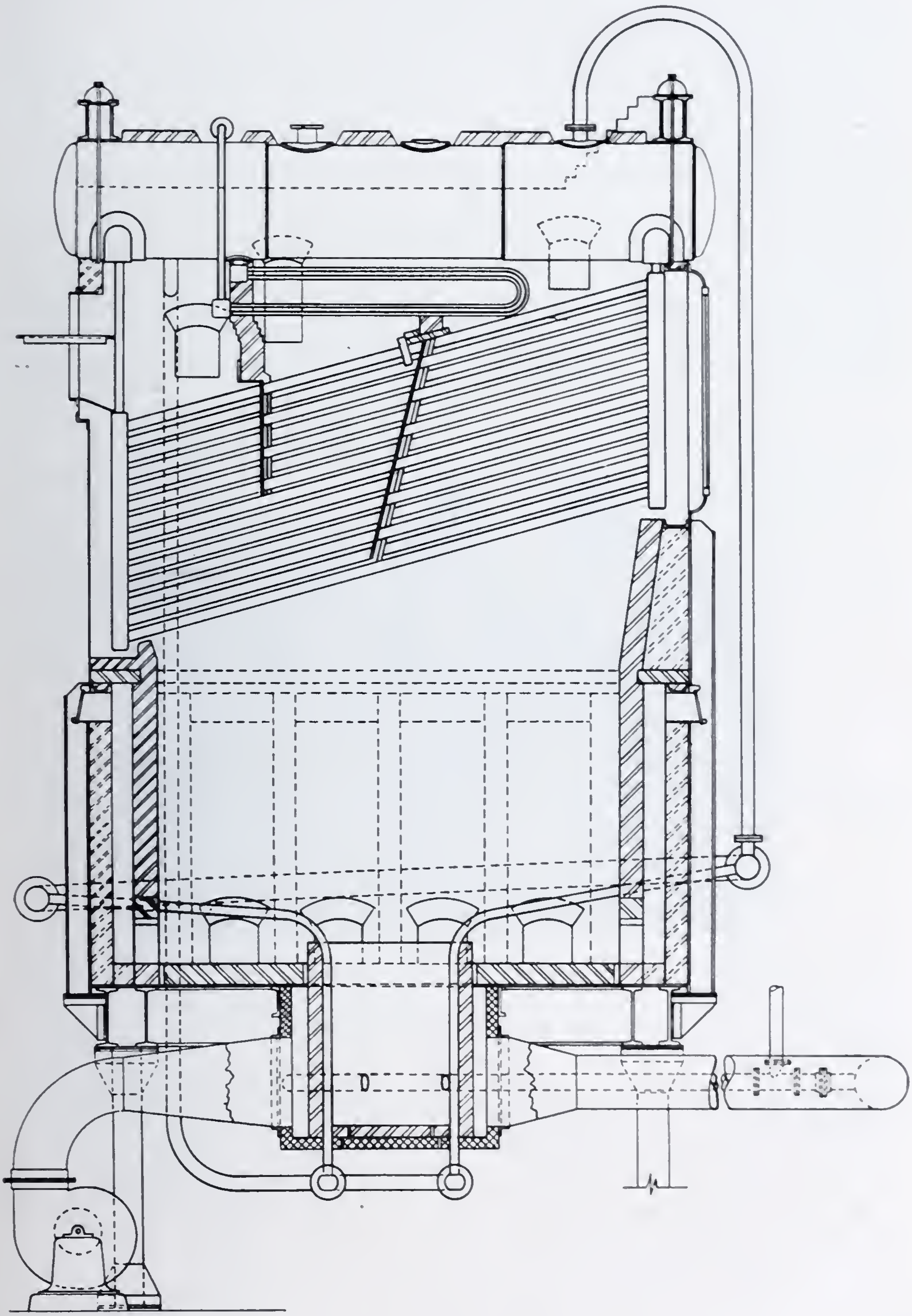

Fig. 10. Section of Vertical Well Furnace and Dispersion Chamber under Boiler.

Engineers will be interested in learning that a well-furnace installation has recently been installed by the Duquesne Light Company at its Brunot Island plant. Another history-making installation of this type, now under course of construction, is that of the Buffalo General Electric Company, where four 1200-horse-power boilers operating up to 550 per cent. of rating will be fired by well furnaces.

It is thus felt that to-day the "well-type" furnace is a demonstrated success; and that, for the first time in the history of pulverized coal, the problem of turbulent flow, and hence the problem of combustion volume, has been solved. Not only may pulverized coal be efficiently burned in combustion volumes as small as those previously

Fig. 11. Eight-Foot Experimental Well Furnace under Fire at Fullerton, Pa.

employed for stokers, but actually smaller furnaces may be installed where necessary. For the first time, completely successful applications of pulverized coal to many industrial and metallurgical furnaces, to transportation and marine service, are made possible; as well as the conversion of present stoker-fired furnaces to the advantages of pulverized coal without the necessity (in many cases) of more than slightly modifying the present furnace construction. Thus many operators who have heretofore found the application of pulverized fuel impracticable on account of high cost of furnace reconstruction, have now made available to them the increased efficiency, economy, and flexibility of pulverized-fuel firing.

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DISCUSSION

J. A. Graham:* What is the smallest size in which this furnace can be built? Would it be practicable to fit one to a tubular boiler of 175-horse-power?

H. W. Brooks: Eventually, there is every reason to anticipate success in the application of the well furnace to the size and type of boiler mentioned. In fact, our patent applications cover the use of this principle under domestic-size furnaces. The results of research to date, however, have been so astonishing and revolutionary that it has been considered the most conservative policy to "make haste slowly" and avoid that engineering by "hunches" with which the whole combustion field of the past has all too frequently been obsessed.

So far, with the exception of a Scotch marine boiler so fired, and shortly to be tested by the United States government, the smallest boiler considered has been of 3000 square feet of heating surface. All pulverized-fuel applications in the present state of the art find increasing difficulty of commercial justification with smaller sizes of individual boiler and plant. As all present designs of well furnace must pass the searching scrutiny of our major engineering executives, and, as their capacity for such detail work when added to their usual duties is distinctly limited, it is necessary that prospective applications at present be most selectively and discriminately chosen. So far, therefore, for every one installation accepted, we have rejected several possibilities which have been offered.

Carl Weigel:† I would like to ask whether there is any merit in having the well vertical with the fire going upward, and whether you have any trouble with slag falling back into the well?

Do you expect to use the horizontal type of well as shown in the Sherman Creek job?

H. W. Brooks: At Sherman Creek, two wells with horizontal axes were installed on the same furnace with one installed on the

*Superintendent of Buildings and Grounds, Shady Side Academy, Pittsburgh.
†Chief Engineer, Walsh & Weidner Boiler Co., Chattanooga, Tenn.

sloping sides of the former ash hopper of the stoker-fired furnace which this installation replaced, and inclined at an angle of 40 degrees with the vertical. Most of the research work at Fullerton has been done on wells with vertical axes. So far, all three types appear to function with equal success.

The extreme turbulence and high velocities in the well apparently inhibit all possibility of return of molten slag particles through the upcoming spiral of flame. The only evidence of deposition on the furnace bottom, so far, has been a small cone a few inches high, which apparently remains of the same size indefinitely. Above the well, in the dispersion chamber, such slag as may be deposited spreads out umbrella fashion and is thrown to the water-cooled sides which cool it and cause it to fall to the floor of the dispersion chamber, whence it is removed in the usual manner.

E. B. Plapp:* Would the speaker care to give any information on the rate of combustion he can get per cubic foot volume per hour; also at what pressure this mixture of coal and air must be blown into the combustion chamber?

H. W. Brooks: The answer to the first question, while interesting technically, may lead to misapprehension if not properly interpreted for practical application. In the well proper and a "mushroom head" shape spaced immediately above and around it, Orsat surveys have indicated with certain fuels and ratings 99 per cent. complete combustion in a volume corresponding to heat releases of 700,000 to 1,000,000 per cubic foot. This, however, utilized but a small portion of the dispersion-chamber volume available. With varying ranges of rating, more of the dispersion-chamber volume was utilized. The extent to which it will eventually be possible to reduce the combined volume of well and dispersion chamber remains for future research to disclose; but present evidence shows that it may be made substantially smaller than either the ordinary stoker-fired furnace or the smallest of previous pulverized-fuel furnaces.

Air velocities utilized to date range from as low as 3500 feet to as high as 8000 feet per minute.

*Mechanical Engineer, U. S. Aluminum Co., New Kensington, Pa.

W. C. BUELL, JR.:* What I can say on the subject under discussion may possibly add a little historical information on the general subject.

The only novelty claimed in the use of the well furnace, as I understand it, is its application to pulverized coal.

In 1905, when I first started along combustion-engineering lines, I was with a firm which was building small furnaces which operated very much on the principle of the well furnace discussed here to-night. These little furnaces were used for melting gold and other precious metals and varied in size from a furnace melting a few ounces to one melting, perhaps, 150 pounds. The combustion rates in these small furnaces show that 700,000 or 800,000 B.t.u. liberated per cubic foot per hour would be quite an ordinary rate. The particular case I have calculated is that of a small crucible furnace with the interior of cylindrical shape, eight inches in diameter and 10 inches deep, which would use about 200 cubic feet per hour of city gas of 600 B.t.u. Making allowance for the space occupied by the crucible, this would show a rate around 800,000 B.t.u.

As a matter of historical interest, I had something to do with a patent case in which it was shown that a type of furnace, with burners fired tangentially to refractory walls and creating a vortex of fire at the center, was used in the United States as early as 1873 and in England several years earlier.

As to the extremely large size of combustion chamber which has been advocated by engineers working on pulverized coal, I want to say that I feel that the maximum size calling for a rate of one pound of coal per cubic foot represents an unnecessary extreme and present practice seems to be swinging to a more rational design with the well-type furnace as the minimum extreme.

For quite a number of years I was interested in the application of fuel-oil to large boiler units, and if the furnaces were designed to release 30,000 to 36,000 B.t.u. per cubic foot per hour no trouble would be encountered with incomplete combustion or refractory failure. I have observed several installations in which peak rates have been maintained for two, three, or four hours, with rates over 50,000 B.t.u. per cubic foot per hour, without refractory failure or bad combustion conditions.

*Engineer, Rust Engineering Co., Pittsburgh.

The large pulverized-coal furnace was, I believe, developed primarily to make allowance for the time factor required in the burning of pulverized coal, for up until a comparatively recent date the combustion-engineering ability displayed in the application of pulverized coal has been of a mediocre order.

Some three or four years ago I had the opportunity of conducting a research on certain industrial-heating equipment in which the same furnace, under both test and practical conditions, used natural gas, fuel-oil and pulverized coal. The question of combustion rates was studied quite carefully at this time. An astounding feature was the relatively low rate of combustion of the pulverized coal as compared with oil, the rate of which in turn was considerably slower than that for natural gas. If coal is air borne, the rate of travel must be above 60 feet a second if it is to remain in suspension, and it is safe to assume that it will be introduced into the furnace at rates not lower than that figured. If commercially pulverized coal requires one to two seconds of time for its complete combustion, it is, of course, clearly apparent that the linear travel within the furnace must be considerable if the completion of the reaction is accomplished.

H. W. Brooks: Limitations of time and the author's estimate of reasonably expectable patience on the part of his audience have prevented any attempt on his part to describe with comprehensive scientific accuracy the fundamental differences of principle employed in the well furnace as compared with attempts of seemingly similar character which upon careful analysis prove essentially different. Many such examples might be cited; for instance, patents were granted on a furnace in which jets of fuel and air were introduced at right angles to each other with the purpose of producing flame impingement on hot, refractory walls in anticipation of re-radiated wall heat expediting the ignition and flame propagation. In contradistinction to this, the well furnace avoids, so far as is practically possible, impingement on hot walls to the extent that it has actually operated at Sherman Creek in a cool well chamber entirely surrounded by water, while at Fullerton the well-furnace action has been reproduced in open air. It is sufficient to say, however, that studies of several years on the part of our patent attorneys and those with whom they have conferred in the various patent offices through-

out the world have yet failed to reveal application of the well-furnace principle in the prior art.

As to comparative rates of flame propagation of gas, oil, and pulverized fuel, it should be recognized that speed of combustion is dependent upon the physical scouring away of films of ash and products of combustion rather than upon rate of chemical combination of carbon and oxygen. Natural molecular diffusivity permits of the chemical reaction taking place explosively or (from an engineering viewpoint) substantially instantaneously. Hence, with equal turbulence, the nearer to molecular size the fuel is introduced into zones of ignition temperatures, the greater the heat release per unit volume.

In connection with oil firing, it may be of interest to note that officials of the United States Navy have informed the writer that the maximum heat release with oil firing attained in battle-ship boilers (and believed by them to be a world's record for this fuel) was 14½ pounds of oil, or 275,000 B.t.u. per cubic foot of furnace volume.

G. G. BELL:* Mr. Brooks has presented a very interesting discussion on the development of furnaces. Personally, I can not see any great advantage in the making of a small well out of tubes connected with the boiler circulation, unless this design permits of a larger percentage of the ash being deposited in the furnace instead of being carried through the boiler.

The previous speaker discussed the size of furnace, and stated that the limits of those that had been constructed had not been very definitely fixed. In the case of our powdered-fuel furnace, the limitation was the temperature in the furnace, which is a function of the boiler rating and the CO_2 being carried. The furnace in this boiler contained 12,500 cubic feet above the water screen, and ratings of 200,000 pounds of steam per hour can be carried with a CO_2 of from 12 to 13 per cent. If a higher CO_2 content is carried at this output, the slag begins to run freely enough on the side walls to cause excessive brickwork erosion.

We have had very good results with carborundum brick in the air-cooled side walls. The slag does not appear to stick to this brick, and apparently it is going to solve the maintenance problem of the side walls of this furnace.

*Manager, Power Development, West Penn Power Co., Pittsburgh.

We make a practice of running the boilers so as to have a low maintenance cost. As we own our own coal mine, one or two per cent. gain in efficiency at high ratings is very easily offset by the increase in boiler maintenance.

In our newer stoker-fired boilers, if we exceed 140,000 to 150,000 pounds of steam per hour and 12 per cent. CO_2, the slag begins to erode the uptake wall. In order to see the effect of water cooling on this wall, we are putting in an experimental installation in one of the boilers. We hope that this will let us get a larger capacity and better efficiency, on account of being able to carry a higher furnace temperature; and will also permit us to reduce the coke in the ash, by enabling us to carry a deeper fire in the clinker-grinder pit without danger of having the slag run down the back-wall and bridge over the clinker-grinder pit, thus giving us greater time to burn the coke out of the ash.

The stoker manufacturer has been up against a difficult job in trying to make guarantees of furnace efficiencies for different types of coal. When more information is available from powdered-fuel furnaces, it should be less difficult to predict the obtainable capacities and efficiencies.

I should like to ask Mr. Brooks whether the larger particles are burned in the well, or the combustion is completed after the particle leaves the well; and where the ash is deposited in the well-type of furnace they have in operation.

J. A. Graham: Is there as large a ratio of radiant heat developed in the well-type furnace as with a stoker, or with powdered coal as used at present? Recent trend in design has been to spread the boiler over a greater horizontal area so that a greater number of tubes can see the fire. Are the characteristics of the well-type furnace such that this will be continued, or will practically all of the heat be absorbed by convection?

H. W. Brooks: The flame of the properly operated well furnace is so nearly transparent as to make observations of the combustion of segregated particles, regardless of their size, impossible. No sparks whatsoever are observable in the furnace. My personal opinion is that the well furnace will make possible as complete combustion as

now obtains in powdered-coal practice with particles at least 20 points larger through 200 mesh than is now believed necessary.

Mr. Bell's question as to ash deposition has been answered previously in the reply to Mr. Weigel. Present available data do not permit convincing comparisons of its quantity with that of the older methods of pulverized-fuel firing.

As radiant heat absorption is a function of the differential of the fourth powers of flame temperatures and those of the heat-absorbing surfaces and, as thermo-couple temperatures within the flame show several hundred degrees hotter than any hitherto demonstrated either in stoker or pulverized-fuel practice, our results to date, as might be expected, have shown radiant-heat absorptions far higher than anything previously known. Simultaneously, due to superior scouring action of the spiral flame on the dead film surrounding the tubes, we apparently also secure superior convection transfer as well. It has been principally these two factors which caused our overall efficiencies at Sherman Creek to prove 2½ to 6 per cent. higher than those of all competitors. Even with the intense temperatures developed, however, we find no excessive wall maintenance necessary with proper wall cooling. Dispersion-chamber walls have given us no worry whatsoever, thermo-couples embedded within ⅛ inch from the inner face of the bricks at the hottest zone showing temperatures well within the range of ordinary number one fire-brick for the coals and ratings employed thus far.

H. C. MEDLEY:* One of the stock arguments of the early protagonists of powdered coal, and of some of its most enthusiastic advocates of the present, has been the great superiority of powdered coal over stokers in the matter of the variety of coals which may be used in the same installation. Will Mr. Brooks please tell us what he considers the practical range for a particular installation; for instance, a powdered-coal furnace designed for high-volatile and low-ash Pittsburgh coal. How far may we go in the direction of the very high-volatile and high-ash Illinois coal; or, on the other hand, the low-volatile semi-bituminous and anthracites? Does powdered-coal firing permit a wider selection of coals than does stoker firing?

*Draftsman, Heyl & Patterson, Inc., Pittsburgh.

H. W. Brooks: Powdered coal has often been more cursed through its too optimistic friends than through its enemies. Such misplaced optimism is furthered by engineers who accept panaceas rather than prescriptions for specific operating conditions, or who confuse technical feasibility with commercial desirability.

In specific answer to Mr. Medley's question (Does powdered-coal firing permit a wider selection of coals than does stoker firing?) the answer is yes, for, if his stoker experience has corresponded with my own, he will agree that *efficient* stoker firing permits little or no selection whatsoever. Properly designed powdered-coal furnaces *will* utilize *efficiently* all coals normally obtainable in a given district. Unless the Interstate Commerce Commission were abolished or there were a general strike in the Pittsburgh and West Virginia fields (and no machinery should ever be construed as catastrophe insurance) you would not normally expect to burn either anthracite or Illinois bituminous; hence you would not care to spend the necessary money to install mills, furnaces, and other equipment to insure your being able to do so. If, then, a catastrophe did arise and you had to utilize substitutes in equipment designed for Pittsburgh coal you should expect an order of results no better than that of the operator of a 250-pound turbine whose boiler inspector suddenly condemns him to 125-pound operation. If, however, you were accustomed to using the better grades of Cambria County Lower Kittanning, and your purchasing agent located a distress lot of Indiana County Upper Freeport at bargain prices, with powdered-coal equipment you could make a lifelong friend of him by permitting the play of his Shylock instinct, while with stokers you would probably hesitate about taking it at any price. On the other hand, some operators are located on the borderlands between coal districts. Such an operator should spend the money for equipment and instruction of operating personnel to burn the worst coals from either source he might reasonably expect, knowing full well that in so doing he is increasing his fixed charges to insure continuity of a reasonably priced continuous coal supply. That this *can* be done where desirable has been evidenced at Binghamton, N. Y., where anthracite culm and central Pennsylvania bituminous coal have been burned in the same furnace; at Noblesville, Ind., where Indiana and West Virginia bituminous have been used; at Milwaukee, where both Pittsburgh and Illinois coal were fired, and at

Birmingham, Ala., where Alabama bituminous and coke braize are used on occasion. None of these plants, however, so far as I am aware, makes a practice of using the two fuels interchangeably, as market conditions do not ordinarily differ sufficiently to justify; thus with proper equipment the alternative operation is quite technically feasible, though seldom commercially desirable.

CARL WEIGEL: In burning oil we often have trouble with the burner acting as a sort of blow-torch, blowing out the tubes. In your well-type furnace you will have a heat more intense than we get from oil burners. Have you had any experience in burning out the tubes immediately over the well?

H. W. BROOKS: The first row of tubes is not sufficiently near the top of the well to have the intense blow-torch action directed against these tubes. By the time the flame reaches the top of the dispersion chamber, much of the most intense heat has been dissipated. Lack of conclusive evidence of the minimum to which this distance may be safely reduced is one of the reasons why we can not yet tell the ultimate minimum B.t.u. per cubic foot of volume of combined well and dispersion chamber. The problem is complicated by the wide variety of boiler feed-water concentrations. Thus far, we know we have allowed a factor of safety larger than necessary in order to play safe. Future designs will be based on actual test experience as we can get it. Eventually, the first row of tubes will be lowered to the minimum possible distance above the top of the well consistent with life of tubes and proper water-wall exposure.

CARL WEIGEL: Is combustion completed within the well or in the dispersion chamber?

H. W. BROOKS: Generally, combustion (according to the Orsat survey made) spreads out into the dispersion chamber in the form of a mushroom head. The exact point of completion of combustion depends on the velocity of the incoming jets, which depends on the rating desired. Incoming jet velocities may either be made so low as to complete all the combustion within the well itself, or increased (thus increasing the pitch of the flame spiral) so that combustion is completed within the dispersion chamber.

G. G. BELL: Are the larger particles burned in the well?

H. W. BROOKS: That, again, depends on the rating. At low ratings they are burned in the well; at high ratings their combustion is completed in the dispersion chamber.

MARTIN FRISCH:* As I understand from Audibert's results, it takes a certain length of time to burn a solid particle of coal. The time depends on the fineness of the particles, the temperature, and many other factors. If coal is burned at a given rate, the particle in order to be completely burned would have to remain in the furnace a certain length of time. As the rate of combustion is increased, the fuel and air quantities are also increased, and hence also the fuel and air velocities increase, tending to reduce the available time. How is the flame controlled to obtain the time required for complete combustion?

If the rating increases, does not the velocity through the furnace increase also, owing to the introduction of more air and coal? The vertical component of the velocity through the furnace must increase because it is determined by the effective cross-section of the furnace and the volume of gas passed through it in unit time. It is not clear that, if the flame is caused to make more revolutions along its helical path before it enters the boiler, the time taken for the fuel particles and the gases to pass from the burner to the boiler will be increased. It would seem that, irrespective of the length of the helical path, the time depends only on the cross-section and the average component velocity along the axis of the helix. As the rating goes up, whether the pitch of the helix be increased or decreased, the time available for the fuel to pass from burner to boiler decreases.

H. W. BROOKS: Except in certain special cases, it has not been found desirable to introduce all air as primary air. By varying the proportion of primary and secondary air, the former may vary between the minimum velocities capable of carrying coal and the maxima consistent with reasonable air horse-power. The pitch of the flame spiral and the linear helical speed are controllable by the velocity of the incoming jets, and hence are not necessarily a function of the total air

*Research Department, Combustion Engineering Corporation, Detroit.

passing through the furnace. In the same article Audibert further shows that speed of combustion is also a function of turbulence and scouring action which, in turn, in this instance depend on speeds of the particles. A particle moving at double the speed, other things being equal, would burn much faster than the more slowly moving particle. As a matter of fact, with heat releases of 800,000 B.t.u. per cubic foot demonstrated as possible and but a small fraction of this desired in practice, little effort need be made to confine completion of combustion within narrowly restricted limits. Even if the distance through the spiral doubled, combustion would still be complete long before the tubes were reached.

J. A. GRAHAM: Is there more ash carried up the chimney than with the flame projected vertically downward?

H. W. BROOKS: This will vary with different coals and pulverizing mills.

T. A. PEEBLES:* While I have not for several years been directly connected with engineering work on pulverized-coal installations, I have been watching the developments with considerable interest.

The latest difficulty to be overcome in the development of powdered coal as a commercial success as a method of firing steam boilers was the disposal of the ash. It was found that fusing of the ash made continuous and efficient operation of the earlier powdered-coal furnaces impossible. The ash fused into a solid mass in the bottom of the furnace or came in contact with the walls and quickly destroyed the fire-brick lining. It was found that a small amount of powdered coal could be burned efficiently in these furnaces without ash and slag troubles, and this led engineers to set a limit on the rate at which heat could be liberated in a furnace of given size. Where high boiler ratings were required, this resulted in furnaces of very large volume and of considerable cost. In some cases the combustion chamber is about as expensive as any single element in the complete steam-generating unit. It has been argued that this cost is justified because the high efficiency and capacity which can be secured make it possible in

*Chief Engineer, Hagan Corporation, Pittsburgh.

this manner to build a boiler plant for a given maximum rate of steam generation at less cost than it could be built with mechanical stokers and small combustion chambers. This may be true in the large central stations where feed-water conditions are excellent, but it is doubtful if it could be applied to the average industrial plant.

There has been a feeling among engineers that it should be possible to burn finely divided coal in a given size of furnace at a rate equal to or greater than that of a stoker-fired furnace, and the information Mr. Brooks has given us indicates that this result has actually been secured. It will be interesting to get the stoker manufacturers' reaction to this development. There is no doubt that better stokers and better stoker furnaces are available to-day than we would have if improvements along this line had not been forced by the competition of pulverized fuel, and it is to be expected that further improvements in stoker-fired furnaces will be made.

The enormous rates of combustion reported by Mr. Brooks are accounted for by the fact that a condition of extreme turbulence is set up in the combustion zone as contrasted with the stream-line flow, which has heretofore been considered desirable in the burning of powdered coal. It is very doubtful if this stream-line flow was ever actually secured in the furnace, but there was at least a condition of slow velocity and the minimum of turbulence. To what extent the stoker furnace can be reduced in size by applying the same methods remains to be seen. It is well known, however, that the rate of combustion in a stoker-fired furnace can be greatly increased in this manner. Many of us remember the enormous amount of smoke produced by some Roney stokers set with small combustion chambers and operated at high ratings. I know of a number of these furnaces where smoke has been eliminated, combustion improved, and the efficiency increased by admitting a quantity of air over the fuel bed in such a manner as to produce a turbulent condition above the fuel bed. The methods used to produce this condition were rather crude, but it is entirely possible that an application of this general idea to stoker-fired furnaces will make possible a substantial reduction in the size and cost of future furnace constructions for stokers as well as for powdered fuel.

H. W. Brooks: I claim the unique distinction of being practically the only known pulverized-fuel engineer who does not look

forward to the early and complete demise of the stoker. Some very able engineers of my acquaintance have installed stokers even within the past few years, and I must confess that I strongly suspect I should have done likewise had I been in their places.

Several years ago I innocently undertook to establish to my own satisfaction the proper line of demarcation between stokers and powdered coal. The pace of development since has been so swift by both competitors that I no sooner establish the line than I must commence afresh to re-establish it. The advent of the well furnace, particularly, completely upset the most nearly fixed conclusions I had gained in several years of study. Were I again functioning as a buyer to-day, and suspected my case in the borderland, I should withhold decision until the latest facts, *including prices*, were completely assembled before me.

To-day as combustion engineers, we are in the position of a physician having two prescriptions where previously he had but one. Eventually it is to be hoped that we shall learn to diagnose properly our patients' cases and apply the proper treatment. Out in Illinois even yet there remain monuments to an analogous phase of a famous stoker controversy in the form of underfeed stokers on Illinois coals.

The truth as to technical superiority between powdered coal and stokers, though not always easy to obtain, is simple compared with the truth concerning "dollar" efficiencies where fixed and operating charges and maintenance are considered. And after all, the ultimate measure of engineering service to society is "dollar" efficiency—not technical (or thermal) efficiency.

Please bear in mind, therefore, that a few of us ultra-conservatives among manufacturers are working just as hard to prevent you from putting in equipment of lesser "dollar" efficiency as you are to protect yourselves against it. We realize that one incorrect installation harms more than ten perfect ones benefit, and hence are rather jealous and careful of the correctness of our engineering judgments.

T. E. Purcell:* Competition between the stoker manufacturers and the manufacturers of pulverized-fuel equipment seems to have been a great incentive in forcing the manufacturers of both types of equipment to develop it to the utmost. The result has been that

*General Superintendent of Power Stations, Duquesne Light Co., Pittsburgh.

they are both now claiming almost unbelievable boiler efficiencies and are both recommending their equipment for installations to which, from the operating man's point of view, they may in some cases not be applicable. It appears to me that the time has now come for some sound reasoning, in order that guarantees which can not be met will not be made.

The decision as to whether stoker or pulverized fuel should be used depends, of course, entirely on what the "dollar" efficiency of the installation is to be. This in turn depends to a great extent on maintenance cost. Up to the present time we have been unable to obtain any reliable figures whatsoever on the maintenance cost of pulverized-fuel equipment, and not much is available on stokers. We are not asking for guarantees on maintenance, but would like some figures which would show what the experience along this line has been.

H. W. Brooks: Combustion engineering has indeed been notoriously and grievously afflicted with engineering by "hunches" and by salesmen. Please be assured that no one recognizes the harm done more forcibly than some of us who are diligently seeking for ourselves and our friends the truth, the whole truth, and nothing but the truth.

As to reliable data on maintenance costs, the most conscientious equipment engineer in the world might easily, yet unwittingly, lead you astray. Maintenance costs may no more be standardized than the minds of the operating engineers who suffer them, nor the chemical and physical characteristics of America's thousands of coals. Maintenance of any piece of equipment is more a function of the intelligence with which it is operated than of the equipment itself.

Mr. Purcell has good equipment, together with the knowledge, skill, and personnel to make it function properly; yet I daresay his maintenance costs turned over to certain other operators not so favorably situated might cause considerable misapprehension and possibly impugnment of his motives and veracity. Mr. Purcell has stated that he does not ask for maintenance guarantees, yet few powdered-coal equipment specifications reach us that do not demand mill maintenance guarantees. Sometimes we wonder whether those who ask them of us are really serious in their requests.

NECROLOGY

Frederick Crabtree

Born February 1, 1867.
Died February 14, 1925.
Joined the Society, March, 1892.
Director, 1914, 1915, 1916.
Vice-President, 1922, 1923.
President, 1924.

We little thought, in January 1924, when he was inducted into office, that we should be called upon to mourn the loss of our President within about a year and with his term of office hardly completed. That this has come upon us is an example of the vicissitudes of life.

Frederick Crabtree was born in Bramley, York, England, February 1, 1867, the son of Joseph and Isabella Crabtree. His parents came to this country when he was quite young. He was educated in the common schools of Lawrence, Mass., graduating from the high school with the class of 1884. He was editor of the school newspaper called *High School Bulletin* during his senior year. He was a hard worker both physically and mentally; circumstances requiring him to assist in providing finances to secure his education. Thus, although he entered the Massachusetts Institute of Technology in the fall of 1884 for the freshman year, he worked at the Beach Soap Company in Lawrence during the next school year. During the last two years of final schooling he served nights as spare watchman at the Pacific Print Works; he also assisted one of the professors in working out problems for a new text-book on mathematics.

Boyhood friends remember with pleasure and gratitude the wholesome friendliness of the older man in school to the freshmen and younger students when commuting back and forth from Lawrence to Boston on the trains. This sincerity and loyalty and exhibition of true manhood endured through all of Fred. Crabtree's life. His mathematical understanding and capacity for sound reasoning were admired by all. He was not only a good student, standing high in his class, but accomplished his work with all of the handicaps required of one who was working his way through school.

Upon graduation from the Massachusetts Institute of Technology with the degree of B. S. in Chemistry, he entered the employ of the Illinois Steel Company as a chemist in 1889. The next year he moved to McKeesport, Pa., and assumed a similar position with the National Tube Company, where he remained for ten years. While here he played the church organ and trained the boy choir in St. Stephen's Church—an example of his continued interest in boyhood's activities.

In 1900 and 1901 he was Superintendent of the Western Steel Company, and a little later he became Superintendent of Blast Furnaces at Pueblo, Colo., for the Colorado Fuel and Iron Company.

In 1904 he took up the duties for which he had always been admirably fitted and recognized by his earlier and younger associates—that of teaching. That year he became Professor of Mining and Metallurgy in the Colorado College at Colorado Springs. In 1906 he was called to the newly established institution at Pittsburgh, the Carnegie Technical Schools, which later became the Carnegie Institute of Technology. His first appointment was that of Assistant Professor of Metallurgy; in 1908 he became Associate Professor of Metallurgy and Mining and, in 1909, he was made full Professor of Metallurgy and Mining Engineering, which position he continued to hold until his death.

While during the early years of service he taught several courses, later he concentrated upon metallurgy and affiliated subjects. His classes were small and his teaching work was therefore of that beneficial informal character which produces directness and helpful influence. This is evidenced by the desire to perpetuate his influence in the form of a scholarship or some other memorial. He was dearly loved by his students for his kindliness and sympathetic realization of their problems.

While upon the faculty of the Carnegie Institute of Technology, Professor Crabtree still continued active work in his chosen field. This was not only of advantage to him, but his students secured the reflected benefit from the fact that he could speak with authority from actually doing things in practice. These engagements were with many of the corporations in Pittsburgh, particularly that of the Jones & Laughlin Steel Corporation.

Professor Crabtree was always loyal and remembered kindly his early associates and training in New England. Upon visits to Lawrence, where he lived for so long with boyhood friends, he never failed, when opportunity presented itself, to call upon old classmates and renew acquaintanceship.

In 1894 Mr. Crabtree married Miss Mary Odessa Moore, of McKeesport, who together with a daughter, Mrs. William Schmertz, 3rd, of Pittsburgh, and a sister, Miss Lizzie M. Crabtree, of Lawrence, Mass., survive him. He was a member of the American Institute of Mining and Metallurgical Engineers; the American Electrochemical Society; the American Society for Steel Treating; and the Iron and Steel Institute. Among his social activities were those as a member of the Pittsburgh Athletic Association. He was a member of the Calvary Protestant Episcopal Church of Pittsburgh. As further evidence of his Christian service and interest in youth, he taught for some time in the Sunday school of this church.

Professor Crabtree joined the Engineers' Society of Western Pennsylvania in March, 1892. While away from the Pittsburgh district he resigned, and was reinstated in June, 1911. He served as Director for three years, during 1914, 1915 and 1916. He was Vice-President and Chairman of Publication Committee during the years 1922 and 1923. He was President during the year 1924 and had just completed his term of office when he died February 14, 1925, at St. Petersburg, Fla.

Professor Crabtree had suffered a nervous breakdown and been under treatment for some weeks. The illness was not considered serious, but after some attention and minor operations he went South for recuperation. It appeared at first that he was growing in strength, but a few days before his death he became seriously ill and there was not sufficient time for the family to reach his bedside after being notified. He died in the service of the Society and the profession.

The engineering profession, in its largest sense, lost a great man in the demise of Professor Crabtree. Thorough in the execution of his work, helpful in his service to young men, kindly in his association with friends; all, young and old, were bound to him with bonds of ever-strengthening friendship. He was a wise counselor and sympathetic friend to the young men. The teaching profession has lost a valued member; the technical fraternity, a strong and upright man,

who stood for best things. His memory will always be dear to us. We feel honored that he could serve us as President, and we now spread this memoir on the records of the Society as our mark of respect to his memory.

Richard Hirsch

Born, Allegheny, Pa., July 2, 1867.
Died, Pittsburgh, Pa., July 5, 1925.
Joined the Society, December, 1894.
Director, 1901, 1902.
Secretary, 1908.

Richard Hirsch was born in the old Fourth Ward of Allegheny, July 2, 1867. He was the son of Joseph M. and Sophia Johnson Hirsch. When but a few months old the family moved to the Second Ward in Pittsburgh. He attended the old South School on Diamond street and graduated from old Central High School in the class of 1885. During that summer he entered the employ of the Harry Hugus Hardware Company on Wood street, and in 1886 he entered the employ of the Atlas Iron Works, where he held a clerical position. In 1887 he went to Painter's Mill, on the South Side, where he was timekeeper. In the early part of 1888 he entered the employ of the H. K. Porter Locomotive Company as blueprint boy, and was with them in the engineering department until 1901, when he became chief draftsman for the Westinghouse Machine Company, remaining with that company until 1908. During 1908 he was Secretary of the Engineers' Society for several months, leaving there to return to the H. K. Porter Company as mechanical engineer, which position he held until his death on July 5, 1925. During 1901 and 1902 he was a Director of the Engineers' Society of Western Pennsylvania and served as Chairman of the Program Committee.

He was an Episcopalian, a vestryman of St. Andrew's Episcopal Church and a member of the Church Club. In 1904 he was married to Sarah Agnes Heaps and had one daughter, Elizabeth Osborne Hirsch.

He was a member of Crescent Lodge No. 576, F. & A. M.; Shiloh Chapter No. 257, R. A. M.; Tancred Commandery No. 48, K. T.; and Pittsburgh Consistory, A. A. S. R.

He was also a member of the Advisory Board of the Public Wash-House and Baths Association.

When the Carnegie Technical Schools were being organized, he lectured for them in some of the nearby towns on the subject of "Compressed Air."

Alexander Louis Hoerr

Born, Pittsburgh, Pa., June 18, 1873.
Died, McKeesport, Pa., January 28, 1924.
Joined the Society in 1903.
President, 1917.

Alexander Louis Hoerr was born on the South Side, Pittsburgh, on June 18, 1873. He was educated in the public schools of Pittsburgh and was graduated with the class of 1895 in the Engineering School of the Western University of Pennsylvania, now the University of Pittsburgh, receiving the degree of Mechanical Engineer. Following graduation he was employed with the Lackawanna Steel Company. Later he was affiliated with the Jones & Laughlin Steel Company at Pittsburgh for several years. Mr. Hoerr then entered the employ of the National Tube Company at its National Works at McKeesport as steam and hydraulic engineer, which position he held for several years, and he was made chief engineer eight years ago. Since that time he had filled this position in such a capable manner that he was considered one of the company's most valued employees.

Mr. Hoerr was a man of good mind and sound judgment based on experience. He took an active interest in civic affairs, serving the community in many capacities. His death is a personal loss to all those who knew him.

Mr. Hoerr was a member of the Board of Directors of the McKeesport Hospital, the McKeesport City Planning Commission, McKeesport Rotary Club, Youghiogheny Country Club, and the American Iron and Steel Institute.

Mr. Hoerr is survived by his wife, Mrs. Emma Louise Hoerr, and three sons, Robert A., Philip K., and Stephen T. Hoerr.

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Wm. Penn Hotel, Tuesday, January 19, at 4:40 P. M., President Walter B. Spellmire presiding, Messrs. Fohl, Leland, Goodspeed, Affelder, Clark, Covell, Edgar, Rankin and the Secretary being present.

The Minutes of the last meeting held Dec. 15th were approved without reading.

Applications for membership from the following gentlemen, having been published to the Society, pursuant to the action of the Board, were elected to membership.

MEMBERS

Baker, David
Baker, David, Jr.
Fairley, Geo E. A.
Fishburn, Cyrus C.
Heald, Kenneth Conrad
McCullough, H. F.
McWade, Frank J.

ASSOCIATE MEMBER

Haworth, Mack E.

JUNIORS

Spencer, Howard F.
Welker, Richard M.

Applications for membership were received from the following gentlemen and their names ordered published to the Society.

MEMBERS

Dyrssen, Waldemar
Graf, Julius E.
McFarlen, Joseph Pettis
Maddox, John DaCosta
Nicholls, John A.
Steidle, Edward

ASSOCIATES

Benedict, John Blakesley
Davis, Paul G.

JUNIORS

Cutler, Day Emerson
Harmon, Forrest Graves
Macy, Theodore E.
Terman, Mark J.

The Secretary presented a request from Mr. Nathan Schein asking to be transferred to the grade of member. After discussion, the Secretary was requested to advise Mr. Schein of his transfer.

The Secretary reported the death of Mr. C. H. Gisin who joined the Society March, 1903 and died Dec. 9, 1925 and Mr. Harry S. Hunter, who joined the Society April, 1901 and died May 7, 1925.

The report of the Secretary, showing the financial condition of the Society at the close of business Dec. 31st, having been audited by the Finance Committee, was approved.

In the absence of the Chairman of the Entertainment Committee, Mr. Clifford, the Secretary reported that arrangements were completed for the Annual Dinner and reservations up to the present time indicated the largest dinner in the history of the Society.

The committee is planning to have another Ladies' Night party Feb. 19th and is also planning some inspection trips in the spring.

Mr. Fohl, Chairman of the Finance Committee presented the following report:

In accordance with our established custom, there has been made an independent audit of the Society's accounts by Mr. Wm. B. Hanson, public accountant. This audit shows the statements which have been rendered you from month to month to have been correct. It also forms the basis of a comprehensive and interesting report by Mr. Hanson on the financial activities of the Society. There follow herewith certain brief excerpts from it, with comments, for which the undersigning chairman must accept responsibility as the time between the receipt of the report and the meeting has been too short to permit its consideration by your Finance Committee as a whole. The Society's net income for 1925 has been as follows:

From Dues and Fees (Entrance)	$19,287.08	
PROCEEDINGS	1,795.91	
Interest Earned	1,103.87	
Sales of Waste Paper, etc.	84.26	
		$22,271.12

The charges against this income were:

To Administration and Gen. Exp.	$19,454.29	
Entertainment and Inspection Trips	770.82	
Depreciation on Furniture and Fixtures	614.30	
Banquet	13.64	
		20,853.05
Net Income from Operations		$ 1,418.07

Attention is directed to the fact that there is still owing to the Permanent Fund $2,845.00 taken from it with the Society's assent, for current uses during the periods of our distress, now almost forgotten. The report shows:

Cash on Hand	$ 500.00	
In Current Accounts	2,359.86	
In Reserve Fund	2,500.00	
In Permanent Fund	5,094.71	
		$10,454.57

The Reserve Fund is seen to be intact. It is suggested that $1,000 might readily be transferred from our current accounts to apply on the debt owing the Permanent Fund reducing that debt to $1,845.00 which it is hoped may be paid out of earnings in 1926. It is further suggested that $5,000.00 be taken from the Permanent Fund and invested in approved securities for the purpose of increasing our earned interest.

It may be of interest to point out that a comparative statement of cash Receipts and Disbursements for the past five years shows deficits for 1921 and 1922; and excess of receipts over disbursements of $4,657.33 in 1923 during which year certain of our industries contributed $5,000 to our support; in 1924 there is shown an excess of $2,680.11 with the industries contributing $1,100.00. In striking contrast to these is 1925, with an excess of receipts over disbursements of $2,521.04 with no contributions from outside sources. The difference between receipts and disbursements does not, of course, accurately reflect net income for the year. But, as that has previously been shown with a balance of $1,418.07 on the right side of the ledger, after making all proper accounting charges, it would appear that the Society is once more a going concern.

After a general discussion, it was moved and carried that the report and recommendations of the Finance Committee be approved and the Secretary authorized to transfer $1,000 from the General Fund to the Permanent Fund to cover a portion of the amount owing that fund for

money used several years ago. It was further moved and carried that the committee be commended on the condition of our finances and the fact that they were able to live within the budget estimated the first of the year.

Mr. Leland, Chairman of the House Committee, reported an evening attendance of 450 for the month of December.

Mr. Affelder, Chairman of the Membership Committee, reported that one meeting of the Committee had been held to transact the regular business of the committee in going over applications and resignations.

The Secretary presented the following report from Mr. Morris Knowles, who was our representative at a meeting of the American Engineering Council held in Washington, Jan. 13th on a National Department of Public Works.

"The meeting of the Engineering Council was attended by some sixty representatives of about the same number of engineering and technical societies in the country. The conference was addressed by Gardner S. Williams, Chairman, Public Works Committee; Hon. Adam M. Wyant of Pennsylvania, Congressman 31st District, author of the Bill to create a Department of Public Works and Domain. This was followed by discussion upon proposed Bill as revised Jan. 1, 1926, and the adoption of the same without amendment; although the Committee was authorized to make such textual changes as may appear necessary from time to time without destroying the intent of the Bill.

The question of state organizations for promotion of work was discussed with the conclusion that the committee should have power to act and secure cooperation of various state organizations. The meeting then adjourned with the understanding that the Bill will be pressed for passage."

After a general discussion of the subject of the creation in the National Government of a Dept. of Public Works, it was moved and carried that the thanks of the Board be extended to Mr. Knowles and the report filed.

The Secretary read a letter from Mr. Knowles thanking the Society for the action taken in regard to the work being done by the Planning Commission on the Geodetic and Topographic Survey of Pittsburgh and Allegheny County, also in appreciation of the reception given the paper by Messrs. Arthur and Randall on "The Geodetic and Topographic Survey of Pittsburgh and Allegheny County.

The President in closing the meeting thanked the Board for their support during his administration and the Board by unanimous vote expressed their appreciation of Mr. Spellmire's leadership during the past year and the work accomplished during his administration.

The meeting adjourned at 5:40 P. M.

K. F. Treschow, *Secretary.*

CIVIL SECTION—ANNUAL MEETING

The Annual Meeting of the Civil Section of the Engineers' Society of Western Pennsylvania was held in the Blue Room, William Penn Hotel, Tuesday, Jan. 5th, at 8:25 P. M., Chairman C. C. Dornbush presiding, 50 members and visitors being present.

The Minutes of the last meeting were read and approved.

The Annual Report of the Chairman of the work done by the Section for the year 1925 was read by the Secretary.

No further business coming before the Section, the Chairman called for the report of the Nominating Committee, which was presented by Mr. H. M. Eastman, Chairman as follows:

To Members and Officers, Civil Section,
Engineers' Society of Western Penna.

DEAR SIRS—Your Nominating Committee met in the Society Room, at 12:30 noon to nominate officers for the Section for the ensuing year, and the following members were nominated:

Chairman	V. R. Covell
Vice Chairman	R. P. Forsberg
Directors	C. S. Davis Richard Irvin C. N. Haggart J. F. Laboon Emil Hensen

There being no further nominations, it was regularly moved and carried that the nominations be closed and the Secretary instructed to cast a unanimous ballot for the nominees, who were thereupon declared elected.

Mr. Dornbush then asked Mr. Covell, Chairman elect to come forward and take charge of the meeting. The Chairman then introduced Mr. C. S. Davis Consulting Engineer of Pittsburgh and Chairman of the Special Committee on Local Aggregates for Concrete, who presented the final report of the Committee in accordance with the published notice.

Mr. Covell asked for suggestions as to the best method of discussing and voting on the report and after a general discussion it was moved and carried that the report be presented by sections and adopted or amended a section at a time.

It was regularly moved and carried that the word "local" be inserted in the title so that it will read "Specifications for Local Aggregates for Concrete."

Fine Aggregates:

Section 1 discussed and unanimously approved.
Section 2 discussed and unanimously approved.
Section 3 discussed and unanimously approved.
Section 4 discussed and unanimously approved.
Section 5 discussed and unanimously approved.

Coarse Aggregates:

Section 1 discussed and unanimously approved.
Section 2 discussed and unanimously approved.
Section 3 discussed and unanimously approved.
Section 4 discussed and unanimously approved.

Under soundness test, it was moved and carried that each of the remaining paragraphs be numbered in sequence, 5, 6, 7, 8 and 9.

Soundness of coarse aggregates definition unanimously approved.

Test on soundness of crushed stone and slag unanimously approved.

Paragraph on the test for soundness of gravel to be determined by the engineer was discussed and unanimously approved.

Paragraph on highway construction discussed and unanimously approved.

Paragraph on abrasion losses by sand and gravel discussed and unanimously approved.

It was moved and carried that the report of the Committee as corrected by this meeting be adopted. The motion carried.

It was moved and carried that a vote of thanks be extended the committee for its splendid work. It was also moved and carried that this report as adopted be printed and copies mailed to the entire membership.

The question of an additional supply on hand which might be purchased by non-members was brought up and discussed and the Secretary was asked whether this could be arranged and advised that at the time of printing an extra thousand could be run off, which could be sold for something like 5c per copy and our printer would be very glad to keep the type standing for six or seven months in order that we might have additional copies run off if necessary.

The question of continuing the committee and having them get together and report back to the Section as to whether they felt they were willing to go into the matter of concrete specifications was brought up and discussed.

After general discussion it was regularly moved and carried that the Committee be continued and that they report back at the next meeting of the Civil Section, making further recommendations on the question of preparing specifications for concrete.

It was further moved and carried that copies of these specifications be sent to Engineering & Contracting and Engineering News-Record and Concrete with the suggestion that they give it mention in their issue.

No further business coming before the Section, the meeting adjourned at 10:30 P. M.

K. F. TRESCHOW, *Secretary.*

ANNUAL MEETING

The Forty-Sixth Annual Meeting of the Engineers' Society of Western Pennsylvania was held in the Ball Room, Wm. Penn Hotel, Tuesday, Jan. 19th, at 8:20 P. M., President Walter B. Spellmire presiding, 400 members and visitors being present.

The Minutes of the last Annual Meeting held Jan. 15th, were read and approved.

The Annual Report of the Board of Direction, which included the reports of the Standing and Special Committees, the Sections and the Treasurer, was read as follows:

REPORT OF BOARD OF DIRECTION

The Board of Direction held ten regular meetings during the year at which the routine business of the Society was transacted.

During the year there were nine regular, the Annual Meeting and one special meeting of the Society. The total attendance was 1372, the average being 125. The maximum attendance was 624 at the April 21st meeting, and the minimum 36 at the June 9th meeting. There was a general discussion at each of the above meetings.

The Board wishes to call the attention of the members to the report of the Entertainment and House Committees to be presented later, with special reference to the increase in activities during the past year. Due to the fact that our finances are now in better shape, as you will hear from the report of our Finance Committee, we have been able to extend our activities and are trying to give our membership those functions in which we believe they are interested.

We will appreciate at all times comments, either favorable or unfavorable as to the work we are doing, as it is only in this way that we can tell whether or not we are giving you what you want.

It will be noted from the report of the House Committee that our attendance in the rooms is increasing steadily, as is the number taking lunch at the engineers' table in the Cafeteria. This committee has, during the past year, endeavored to encourage our members to make use of our rooms in giving informal chess tournaments and bridge tournaments in addition to our technical and social activities.

We also wish to call your attention again to the fact that the Secretary's office is endeavoring to give you all the privileges of the usual club in securing for you railroad transportation, rooms at the hotel for your out-of-town guests, theatre tickets and arrangements for small luncheons or dinners you may care to hold in the Wm. Penn Hotel.

Respectfully submitted,

K. F. Treschow, *Secretary.*

REPORT OF ENTERTAINMENT COMMITTEE

To the Board of Direction,
Engineers' Society of Western Penna.

Dear Sirs—The following entertainments and inspection trips were held during the past year.

January 26th—Annual Banquet. Attendance, 972.

March 27th—Ladies' Night Party. Attendance, 110.

March to May—Chess Tournament. Contestants, 24. Cup won by E. Dym.

May 1st—Theatre Party, Merry Wives of Windsor. Attendance, 420.

May 23rd-24th—Inspection Trip to Buffalo and Niagara Falls. Dunlop Tire & Rubber Co., Buffalo; Buffalo-General Electric Co., Buffalo; Niagara Falls Power Plant, Niagara Falls, N. Y. Attendance, 30. Total receipts, $827.80; total expenditures, $988.60; deficit, $160.80.

June 23rd, July 17th, August 17th—Golf Tournament. Attendance, 91. Cup won by J. I. Alexander.

October, May—Bridge Tournament. Contestants, 48. Cups won by J. I. Alexander and W. B. Skinkle.

October 16th—Ladies' Night Party. Attendance, 109. Receipts, $115.50; expenditures, $167.00; deficit, $51.50.

November 21st—Inspection Trip. American Window Glass Company, Jeannette. Attendance, 110.

December 11th—Ladies' Night Party. Attendance, 118. Receipts, $177.00; expenditures, $235.00; deficit, $58.00.

The Committee has been very pleased with the increased interest in our Ladies' Night parties and believe them to be an important part of the work of the Society. They, therefore, recommend that the Entertainment Committee for the coming year hold at least four of these parties during the year.

The Committee has found during the past two years that the interest in general inspection trips is not as active as it was some time ago. This is probably due to the increased demands on our members' time and to the fact that they do not like to take their Saturday afternoons for these trips. We have, therefore, cut down the number of these trips durng the past year to two or three and the long distance trip which it is believed should be made an annual event. It has also been found that practically all the plants in this district are closed Saturday afternoons.

Respectfully submitted,

T. C. Clifford, *Chairman.*

REPORT OF FINANCE COMMITTEE

To the Board of Direction,
Engineers' Society of Western Penna.

DEAR SIRS—In accordance with our established custom, there has been made an independent audit of the Society's accounts by Mr. Wm. B. Hanson, public accountant. This audit shows the statements which have been rendered you from month to month to have been correct. It also forms the basis of a comprehensive and interesting report by Mr. Hanson on the financial activities of the Society. There follow therewith certain brief excerpts from it with comments for which the undersigning chairman must accept responsibility as the time between the receipt of the report and this meeting has been too brief to permit its consideration by your Finance Committee as a whole.

The Society's net income for 1925 has been as follows:

From Dues and Entrance Fees	$19,287.08	
Proceedings	1,795.91	
Interest Earned	1,103.87	
Sales of Waste Paper, etc.	84.26	
		$22,271.12

The charges against this income were:

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Depreciation on Furniture and Fixtures	614.30	
Banquet	13.64	
		20,853.05
Net Income from Operations		$ 1,418.07

Attention is directed to the fact that there is still owing to the Permanent Fund $2,845.00 taken from it with the Society's assent, for current uses during the periods of our distress, now almost forgotten. The report shows:

Cash on Hand	$ 500.00	
In Current Accounts	2,359.86	
In Reserve Fund	2,500.00	
In Permanent Fund	5,094.71	
		$10,454.57

The Reserve Fund is seen to be intact. It is suggested that $1,000.00 might readily be transferred from our current accounts to apply on the debt owing the Permanent Fund reducing that debt to $1,845.00 which it is hoped may be paid out of earnings in 1926. It is further suggested that $5,000.00 be taken from the Permanent Fund and invested in approved securities for the purpose of increasing our earned interest.

It may be of interest to point out that a comparative statement of Cash Receipts and Disbursements for the past five years shows defficts for 1921 and 1922; and excess of receipts over disbursements of $4,657.33 in 1923 during which year certain of our industries contributed $5,000.00 to our support; in 1924 there is shown an excess of $2,680.11 with the industries contributing $1,100.00. In striking contrast to these is 1925, with an excess of receipts over disbursements of $2,521.04, with no contributions from outside sources. The difference between receipts and disbursements does not, of course, accurately reflect net income for the year. But, as that has previously been shown with a balance of $1,418.07 on the right side of the ledger after making all proper accounting charges, it would appear that the Society is once more a going concern.

Respectfully submitted,
W. E. FOHL, *Chairman, Finance Committee.*

REPORT OF MEMBERSHIP COMMITTEE

To the Board of Direction,
Engineers' Society of Western Pennsylvania

DEAR SIRS—Ten meetings of the Committee were held during the year 1925 to assign applications received to the various grades of membership and transact any other business coming up for their attention.

207 new members were elected during the year, and the membership at this time is about 1573.

The assistance and cooperation of the men making up the Membership Committee are gratefully acknowledged. At the close of the year, the membership of the Society was as follows:

Honorary Members	1
Members	1,227
Associate Members	149
Associates	69
Juniors	100
Student Juniors	6
	1,552
Dropped	4
Resignations	40
Removed by Death	18
	62
Accessions	207

Respectfully submitted,
W. L. AFFELDER, *Chairman.*

REPORT OF PUBLICATION COMMITTEE

To the Board of Direction,
Engineers' Society of Western Penna.

DEAR SIRS—During the year three meetings of the Committee were held with an average attendance of four.

Papers Presented at the General Society Meetings	11
Section Meetings	18

Three meetings of the Practising Engineers' Section were held during the year for discussion of the business of the Section.

Twenty of the papers presented have been publishd in the PROCEEDINGS or will be published later. The publication of the PROCEEDINGS is now up to date.

Respectfully submitted,
G. M. GOODSPEED, *Chairman.*

REPORT OF TREASURER

To the Board of Direction,
Engineers' Society of Western Penna.

Dear Sirs—Your Treasurer desires leave to submit the following report for the year 1925 as follows:

Receipts

Dues Collected	$18,035.11	
Entrance Fees	815.00	
Sale of Advertising Space	6,072.85	
Sale of Magazine (Proceedings)	888.83	
Sale of Society Pins	156.00	
Interest on Bonds	690.00	
Lnterest on Bank Balances	413.87	
Income from Banquet	6,580.00	
Sale of Inspection Trip Tickets	937.55	
Ladies' Night Entertainments	456.00	
Golf Tournament	487.34	
Blast Furnace Conference Dinner	259.00	
Sale of Waste Paper & Electroplates	44.76	
Miscellaneous	23.50	
Total Normal Receipts		$35,859.81

Disbursements

Administrative and General	$10,013.63	
Cost of Magazine (Proceedings)	4,443.29	
Furniture and Fixtures	256.84	
Inspection Trips	1,192.41	
Golf Tournament	592.04	
Ladies' Night Entertainments	755.31	
Blast Furnace Conference	337.20	
Other Entertainments	33.75	
Annual Banquet—1925	6,449.41	
Annual Banquet—1926	264.89	
Total Normal Disbursements		$33,338.77

Cash Assets

	Dec. 31, 1924	Dec. 31, 1925
Permanent Fund (Bonds)	$13,615.00	$13,807.50
Cash (Fidelity T. & T. Co.)	4,164.71	5,094.71
Reserve Fund:		
Cash (Fidelity T. & T. Co.)	2,500.00	2,500.00
General Fund:		
Cash (First National Bank)	953.82	2,214.66
Total	$21,233.53	$23,616.87
Increase in Assets	2,383.34	
	$23,616.87	

1—$1,000 Butler Water Company 30-year Bond, maturing September 2, 1931—No. 9 .... $ 940.00

2—$1,000 Connellsville Water Company 5%, Nos. 317-318, maturing October 1, 1939 .... 1,720.00

2—$1,000 Portsmouth, Berkley & Suffolk Water Company 5%, Nos. 465-66, maturing Nov. 1, 1944	1,960.00
2—$1,000 Jamison Coal & Coke Company 5%, Nos. 1502-03, maturing May 1, 1931	2,020.00
2—$1,000 Union Steel Company 5%, Nos. 38642-38643, maturing December 1, 1952	2,120.00
2—$1,000 Pennsylvania Railroad Company 4½%, Nos. 27320-27321, maturing Aug. 1, 1960	1,972.50
3—$1,000 Jones & Laughlin Steel Corporation 5%, Nos. 3020-21-30 maturing May 1, 1939	3,075.00

I am glad to state that the market value of all bonds owned by the Society have increased in value $192.50 during the past year.

Respectfully submitted,
A. STUCKI, *Treasurer.*

REPORT OF HOUSE COMMITTEE

To the Board of Direction,
Engineers' Society of Western Pennsylvania

DEAR SIRS—In presenting the Annual Report of the House Committee, I wish to advise that we had an evening attendance of 4273 for the year 1925, which is an increase of 417 over last year. This makes an increase in attendance since the opening of the new club room of 1954.

The marked increase in the use of our club rooms during the day, particularly around the noon hour, is also very gratifying.

Respectfully submitted,
E. D. LELAND, *Chairman.*

ONE HUNDRED-FOOT STANDARD COMMITTEE

To the Board of Direction,
Engineers' Society of Western Pennsylvania

DEAR SIRS—In submitting herewith the report of your 100-Foot Standard Committee of the Engineers' Society, the members of the committee felt that it would be well to state in the call for meeting that the final report of the 100-Foot Standard Committee will be presented recommending the discontinuance of its work. This in order that anybody who has any objection to the discontinuance of the work may have an opportunity of stating their objections.

This Committee during its long term of service has done very little constructive work. The conditions since its appointment have so changed as to render it in their opinion inadvisable to establish the standard in the City-County Building as was originally proposed.

As the Engineers' Society has incurred no expense with reference to this matter, it seems to us that the matter can be best disposed of by the discharge of the Committee.

Respectfully submitted,
LOUIS P. BLUM, *Chairman.*

REPORT OF CIVIL SECTION

To the Board of Direction,
Engineers' Society of Western Pennsylvania

Dear Sirs—I wish to submit a report of the work done by the Civil Section during the year 1925.

Five regular meetings of the Section were held during the year, the average attendance being 58; the maximum being at the March 3rd meeting with an attendance of 102 and the minimum at the May 5th meeting with an attendance of 37. The average number discussing papers was 8.

January 13th—Annual meeting. "Safety and Construction Standards for Transmission Lines," by James S. Martin, Structural Engineer, Philadelphia Company.

March 3rd—"The Bridge Raising Program on the Allegheny River," by Mr. V. R. Covell, County Engineer, Department of Public Works, Allegheny County.

May 5th—"One Measure of Permanent Relief of Traffic Congestion in the Downtown District—An Inter-District Traffic Circuit," by Frederic Bigger, Architect and Town Planner, Pittsburgh.

September 17th—"Report of Committee on Concrete Aggregates," by C. S. Davis, Consulting Engineer, Pittsburgh.

November 3rd—"Architectural Practice," by Edward B. Lee, Architect, Pittsburgh.

Respectfully submitted,
C. C. Dornbush, *Chairman.*

REPORT OF MECHANICAL SECTION

To the Board of Direction,
Engineers' Society of Western Pennsylvania

Dear Sirs—I submit herewith report of the work done by the Mechanical Section during the year 1925.

Four meetings of the Section were held jointly with the Pittsburgh Section of the American Society of Mechanical Engineers, the average attendance being 74; the maximum being at the October 6th meeting with an attendance of 90, and the minimum being 41 at the February 2nd meeting. The average number discussing the papers was 7.

February 2nd—Annual meeting. "Some Aspects of Oxygen Enrichment of Combustion Air in Heating Furnace Practice," by W. C. Buell, Jr., Mechanical Engineer, Pittsburgh, Pa.

April 7th—"Surface Condensers," by J. E. Goodwillie, Engineer, Ingersoll-Rand Co., New York, N. Y.

October 6th—"Fundamentals in Conditioning of Boiler Waters," by R. E. Hall, Physical Chemist, U. S. Bureau of Mines.

December 8th—"Evolution of Combustion volumes in Pulverized Fuel Boiler Furnace Design," by H. W. Brooks, Consulting Engineer, Fuller-Lehigh Company, Fullerton, Pa.

Respectfully submitted,
Charles H. Clark, *Chairman.*

REPORT OF MINING SECTION

To the Board of Direction,
Engineers' Society of Western Pennsylvania

DEAR SIRS—I submit herewith report of work done by the Mining Section during the year 1925:

Five regular meetings of the Section were held during the year. The average attendance at these meetings was 61, the maximum being at the April 28th meeting, the attendance being 75 and the minimum at the November 25th meeting with an attendance of 48. An average of 13 participated in the discussion. Papers presented are:

February 24th—Annual meeting. "Automatic Control Equipments in Coal Mines," by C. E. H. Von Sothern, Engineer, General Electric Company, Schenectady, N. Y.

April 28th—"Mechanical Coal Loading," by Norton C. Newdick, President, The Coloder Company, Columbus, O.

June 16th—"The Turning Point in Coal," by C. E. Lesher, Assistant to President, Pittsburgh Coal Company, Pittsburgh, Pa.

September 29th—"Improved Preparation for Pittsburgh Coal," Col. Warren R. Roberts, resident, Roberts & Schaefer Company, Chicago, Ill.

November 25th—"Failure of Concrete Shaft Linings at Pennsylvania Bituminous Coal Mines," by N. G. Alford, Vice President, Howard N. Eavenson & Associates, Pittsburgh, Pa.

Respectfully submitted,
N. G. ALFORD, *Chairman.*

REPORT OF PRACTISING ENGINEERS' SECTION

To the Board of Direction,
Engineers' Society of Western Pennsylvania

DEAR SIRS—I wish to submit herewith report of the Practising Engineers' Section of the work done during the year 1925.

Three meetings of the Section were held during the year. The attendance at these meetings was 49; there being 20 at the Fbruary 18th meeting 20 at the November 18th meeting and 9 at the January 21st meeting.

Routine business was discussed at these meetings and an amendment made on the schedule of prices to be charged.

Respectfully submitted,
H. H. RANKIN, *Chairman*

REPORT OF STEEL WORKS SECTION

To the Board of Direction,
Engineers' Society of Western Pennsylvania

DEAR SIRS—I wish to submit herewith report of the Steel Works Section of the work done during the year 1925.

Four meetings of the Section were held during the year. The average attendance at these meetings was 90, the maximum being 200 at the November 12th meeting and the minimum 37 at the May 26th meeting. An average of 14 participated in the discussion of the papers presented.

The papers presented were:

January 27th—Annual meeting. "Concentration in Boilers," by Grant D. Bradshaw, Andrews-Bradshaw Company, Pittsburgh.

March 31st—"Production of Sponge Iron," by E. P. Barrett, U. S. Bureau of Mines, Pittsburgh.

May 26th—"Suspended Arches," by Louis Ellman, District Manager, M. H. Detrich Company, Pittsburgh.

November 12th—Blast Furnace Conference. "Some Observations Regarding Blast Furnace Design," by A. G. McKee, President, A. C. McKee & Company, Cleveland, Ohio. "Modern Blast Furnace Stoves," by A. E. Maccoun, Superintendent, Blast Furnaces, Edgar Thomson Works, Carnegie Steel Company, Braddock, Pa. "Effect of Physical Properties of Ore and Coke on Capacity of the Blast Furnace," T. L. Joseph and P. H. Royster, Metallurgists and S. P. Kinney, Supervising Ferrous Metallurgist, U. S. Bureau of Mines, Pittsburgh. "A Method of Determining Comparable Blowing Practices for Iron Blast Furnaces," J. S. Fulton, Special Representative, Ingersoll-Rand Company, Pittsburgh.

Respectfully submitted,
L. C. Edgar, *Chairman.*

The petition for the formation of an Electrical Section, having been approved by the Board of Direction at its regular meeting held Dec. 15th, 1925, was, pursuant to due notice, brought before the Society for action.

On motion, duly seconded and carried unanimously, it was ordered that an Electrical Section of the Society be formed in accordance with the petition.

President Spellmire: One of the provisions of the By-Laws is that the papers which are presented throughout each year be scrutinized very carefully by a Committee known as the Medal Awards Committee. When a paper is found which possesses unusual merit, we reward the author of such paper by presenting him with a medal in recognition of the merit of the paper. Often times, a number of years will go by without an award being made. This year, we have the pleasure of awarding a medal to the author of a paper, subject "The Solution of the Transportation, Parking and Flood Problems of Pittsburgh." We all know about the 218 acres in this Golden Triangle of ours, and all of us and all of our friends and visitors try to get into the little space at the same time. Sometimes even the rivers contend with us for the occupancy of that space. The paper referred to on this subject was presented by Mr. E. K. Morse, Past President of this Society, and without further remark I invite Mr. Morse to come forward and accept this expression of the appreciation of the Engineers' Society of Western Pennsylvania.

Mr. Morse replied by thanking the Society for the honor conferred upon him.

President Spellmire: This being the Annual Meeting, it is the time when new officers take their respective stations and places. An election has been held in accordance with the requirements of the By-Laws, and the ballots were counted at noon to-day, I ask the Chairman of the Board of Tellers to present the report of that election.

To the Members,
Engineers' Society of Western Pennsylvania

Dear Sirs—The undersigned Tellers publicly canvassed the ballots in the Annual election of officers of the Society at Noon, Tuesday, January 19th, 1926, and wish to report as follows:

Ballots received	469
Irregular ballots	2
Ballots counted	467

For President ....Wm. E. Fohl
For Vice President........................ ....John A. Hunter
For Treasurer ....A Stucki
For Directors.. { L. C. Edgar / H. N. Eavenson

Respectfully submitted,
J. I. ALEXANDER, *Chairman,*
H. A. INGRAM,
J. F. LABOON,
Tellers.

The President thereupon declared the following gentlemen elected.

For President..Wm. E. Fohl

For Vice President...John A. Hunter

For Directors.. { H. N. Eavenson / L. C. Edgar

President Spellmire: Whereas I have enjoyed the honor of being President of this Society during the past year, I now give place to one who can more ably carry on the work. In accordance with the time honored custom, I now call upon two of our senior past presidents, Mr. Morse and Mr. Neilson, to escort the newly elected President to the Chair. I welcome to the chair Mr. W. E. Fohl. If he enjoys the work as much as I have, he will be happy indeed.

President Fohl: Mr. Spellmire and gentlemen: I appreciate very highly the honor you have conferred upon me by this election. I appreciate also that this election was not held merely to pay honor to me and my newly elected colleagues, Messrs. Eavenson, Hunter and Edgar. I think we must view this election as a call from the Society to service. I believe we are all very willing to tender that service; but in order to do that effectively we must have help from the Society at large. Some of you must serve on our various committees; some of you must dig down into your experience and bring up papers which will be interesting and instructive; and numbers of you must constitute yourselves audiences to listen to those papers and share in the dicussion of them. And, finally, in larger numbers, you will have to practice writing your names in a flowing hand on checks for $15.00. We ask your assistance in all these various particulars to the end that the work of the Society may be carried on in the same successful manner that has obtained during the past year, and that we may turn over its affairs to the next administration in the same excellent shape they now are.

That being disposed of, we are now ready for the real treat of the evening, the address of the retiring President, on the subject of "Steam Railroad Electrification."

On motion duly seconded and carried a vote of thanks was extended to Mr. Spellmire for his very excellent paper.

The meeting adjourned at 10:30 P. M.

K. F. TRESCHOW, *Secretary.*

MINING SECTION—ANNUAL MEETING

The Annual Meeting of the Mining Section of the Engineers' Society of Western Pennsylvania was held in the Blue Room, William Penn Hotel, Tuesday evening, Jan. 26th, at 8:17 P. M., Chairman N. G. Alford presiding, 45 members and visitors being present.

The Minutes of the last Annual Meeting were read and approved.

The Annual report of the Section was read by the Secretary.

The report of the Nominating Committee was read by Mr. G. S. Baton Chairman, as follows:

To Members and Officers,
Mining Section

DEAR SIRS—The Nominating Committee appointed to nominate officers for the Mining Section for the ensuing year held a meeting Tuesday, Jan. 26th, and submit the following members for officers of the Section.

Chairman	N. F. Hopkins
Vice Chairman	T. G. Fear
Directors	R. M. Black M. D. Gibson W. R. Jarvis C. E. Lesher L. O. Lougee

Respectfully submitted,

G. S. BATON, *Chairman,*
T. F. WEBSTER,
T. M. OSLER,
Nominating Committee.

On motion the nominations were closed and the Secretary instructed to cast a unanimous ballot in favor of the officers named and they were, thereupon declared elected.

There being no further business, the paper of the evening was presented by Dr. R. E. Somers, Professor of Geology, University of Pittsburgh, Pittsburgh, Pa., on "Mining for Oil."

The ensuing discussion was participated in by: N. G. Alford, V. P., Howard N. Eavenson & Asociates; H. T. Coles, Engr, Charles Hyde & Co.; K. B. Conway, Asst. Secy, Gulf Refining Co.; Ralph E. Davis, Engr, Pittsburgh; Charles R. Fettke, Mining Geologist, Carnegie Inst. of Technology; W. R. Hart, Engr, with Ralph E. Davis; N. F. Hopkins, Civil & Mining Engr, Harrop & Hopkins; Norwood P. Johnston, Engr, Pittsburgh; L. C. Karrick, Engr, U. S. Bureau of Mines; and the author.

On motion duly seconded and carried, a vote of thanks was extended to the author for his very interesting paper.

The meeting adjourned at 10:35 P. M.

K. F. TRESCHOW, *Secretary.*

Vol. 42 MARCH 1926 No. 2

PROCEEDINGS

OF THE

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA

CONTENTS

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Incorporated 1880

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FAILURE OF CONCRETE SHAFT LININGS AT PENNSYLVANIA BITUMINOUS COAL-MINES*

By N. G. Alford†

Shaft lining with concrete in the United States is 22 years old, beginning with the first installation at Gary, W. Va., in 1903. The practice broadened until it became practically universal not only in the many coal-mine shafts sunk from 1915 to 1920, but at metal mines as well.

In 1921 two concrete lining failures at western Pennsylvania mines led to a survey of the condition of the installations in the bituminous coal fields of the state. This study was confined to central and western Pennsylvania; there was no organized effort to extend the investigation beyond the state, and no decided lining failures have yet been reported outside of this district.

Of 106 installations in central and western Pennsylvania, 30 (28 per cent.) have been distinct failures. In all but six cases these linings gave trouble within two years. No fault can be found with the cement, because good grades were used in all cases. The aggregate in 17 of the failures was approved sand and gravel; in the remainder it was either gravel and crushed sandstone, gravel and crushed limestone and sandstone, slag and sand, or simply crushed sandstone.

In nine cases the workmanship was reported as either "fair" or "bad," but these terms are so relative for comparison that they mean little, and if the work was not of the best practice the blame should doubtless be shared by the coal company and should not be borne entirely by the contractor. This involves the chuting of the wet concrete into the forms through conveyor pipes of either rigid or flexible design with a consequent doubt as to whether the cement is thoroughly mixed with the other ingredients in the form, or if disproportionate quantities of the cement are floated to the surface of the batch. This question, with numerous others, can easily result in controversy that should be anticipated in properly drawn specifications.

In all of the failures, lack of sufficient drainage for the lining has been the outstanding difficulty, and in these cases leakage was esti-

*Presented November 24, 1925. Received for publication January 19, 1926.
†Howard N. Eavenson & Associates, Pittsburgh.

mated at anywhere from mere seepage to 50 gallons per minute. Severe temperature changes with alternate freezing and thawing of the leakage destroyed the surface of the lining and, after the face had scaled off, a disintegrated mass was invariably found beneath.

Undoubtedly the greatest problem is determining the amount of drainage required. One or two holes were drilled outside a few of the linings that failed without carrying away the water, but these linings were not supplied either with bleeder pipes or water rings, which experience shows are absolutely essential to the successful handling of water where its pressure is strong enough for penetration. Where grout was used to seal off water permanently it was nowhere reported as successful, which indicates that it should be used only as an aid to sinking. In many of the successful linings, no drainage of any kind was supplied, and the success of these linings to date can be attributed only to the dryness of the strata where they were placed.

One company with 18 concrete linings has, within the past year, drilled from one to three holes outside the shafts to carry water to the bottom and to stop penetration of the concrete. Afterward, the linings were dry, the faulty sections of the linings were repaired, and so far the result is satisfactory, but the work has yet to pass through the season of greatest temperature variation which at the same time furnishes the largest amounts of water. This company has one shaft in which three concrete linings were built within nine years.

Another company, with not quite so many installations, states that concrete linings are impractical for downcast shafts.

Good concreting practice demands that the mixture should have all the density possible. Uniform density can best be maintained by checking the mix volume with actual weights at sufficient intervals to avoid erroneous volume measurement caused by the swelling of damp sand. During at least the first 48 hours of setting the concrete should be entirely protected from contact with shaft water. The cost of this protection in some cases will be high, depending on the amount of water in the strata and to a much less degree on the ingenuity of both the designing engineer and the contractor.

A typical failure, later identified as Shaft No. 9, is an intake airway that was sunk and lined in 1915. Fig. 1 is a section of this shaft. This was an especially difficult condition in that the shaft sinking was practically dry, with water pressure developing later on.

The lining mixture was 1 : 2½ : 5, with a standard grade of Portland cement and Allegheny River sand and gravel. Allegheny River sand and gravel were supplied because they are freer from foreign matter than that dredged from the Monongahela River. No waterproofing was used, no grouting was done, and no water rings installed. The concrete was placed densely in accordance with good workmanship. The curtain-wall, which was four inches thick and reinforced with vertical wires on about 15-inch centers, had a mixture of 1 : 2 : 3 with the same cement and aggregate as the lining. The shaft, which is about 215 feet deep, is entirely through rock, and, while it was being sunk, practically no water was encountered. Shortly after the shaft was completed the lining became wet near the surface and a drill hole was put down behind the shaft to relieve water pressure.

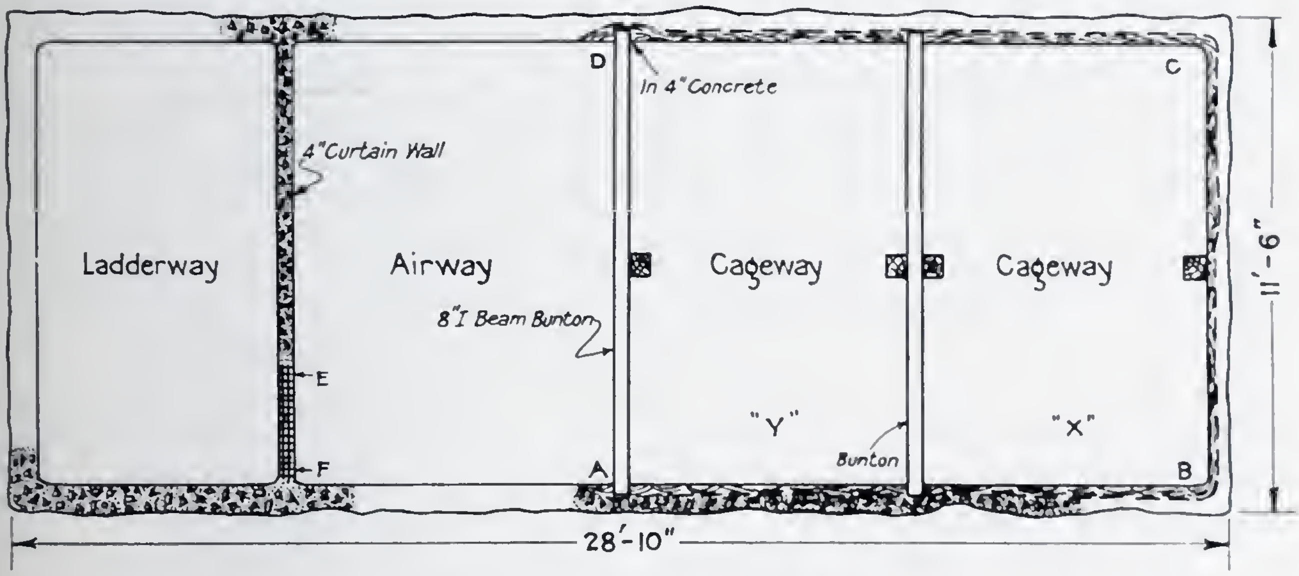

Fig. 1. Section of Shaft.

In the spring of 1922, after the last thaw, the surface of the lining began to scale off in small sections about an eighth of an inch thick. Very little additional disintegration took place until the winter of 1922-1923. The alternate freezing and thawing during that winter continued the process of scaling, and, when spring came, the disintegration had taken off as much as from four to five inches from the face of the lining opposite the cage ways, as shown at *A*, *B*, *C*, and *D* in Fig. 1. The curtain-wall from *E* to *F* was entirely destroyed so that nothing was left of it except the bare reinforcing.

The action began about 45 feet below the surface and continued to the bottom of the shaft. In many places the concrete had completely fallen away from the ends of the steel buntons that held the

guides, and in several instances the buntons were loose at the ends and supported altogether by the guides. In places in the lining the concrete had entirely fallen out, showing the rock. In many places the concrete had a soft, rotten appearance and was easily dug out with a pick. In one or two cases, where a very small stream of water percolated through the concrete, there were deposits of white, mushy material that looked very much like lime. In cold weather the ice around the lining frequently required trimming with picks so that the cages could have clearance. The lining at the ends of the airway section was intact and the surface of the concrete was apparently perfect.

The air entering this shaft amounts to 50,000 cubic feet per minute, which is about one-fourth of the total intake for the mine. The concrete lining was recently replaced by a brick lining.

Data regarding the 30 linings that failed are given in tables I-III.

Table I relates to shaft No. 9, referred to above, in which concrete was replaced by brick lining in November 1925.

In shaft 12, concrete was replaced by brick lining, completed October 1925. In shaft 14, the shaft was relined with concrete in 1924. In shafts 18 and 19, concrete was mixed thin, on the surface and poured through six-inch pipe to the forms. Cement scaled off the surface in honeycombed condition was found in the body of the concrete. Water pressure doubtless separated cement from the slag aggregate despite bleeder pipes inserted to relieve the pressure. In shaft 20, an excess of water was used, but the mix was well spaded.

Shaft 23 was relined in 1921 with new two-inch drain lines. In 1923 drain lines became choked and shaft became wet. Two bore holes were sunk outside the lining, draining the water to the bottom. The shaft is now dry. In shaft 25, holes were drilled outside of the lining in 1924. In shaft 26, water worked through the concrete, and freezing and disintegration ensued. The lining was replaced in 1923 by 1 : 2 : 4 and "Medusa" waterproofing powder. Rings were cut in the old concrete and strata where water flowed. A two-inch pipe conducts the water to the bottom. The shaft is now practically dry. In shaft 28, piers at the shaft bottom were replaced and part of the line resurfaced in 1921.

A study of the conditions in both the successful and failed linings brings a conclusion that concrete lining practice may be improved by:

1. Sufficient drainage behind the lining to relieve natural water

TABLE I. DATA ON FAILURE OF CONCRETE SHAFT LININGS

	INSTALLATION	1	2	3	4	5	6	7	8	9	10
1	Date shaft was sunk	1917	1917	1918	1917	1918	1917	1917	1920	1915	1917
2	Date lining was installed	1917	1917	1918	1917	1918	1917	1917	1920	1915	1917
3	Downcast or upcast	Downcast	Downcast	Upcast	Both	Both	Downcast	Both	Downcast	Downcast	Upcast
4	Is shaft wet?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
5	When did wetness start?	Sept. 1919	Mar. 1920	1920	At once	At once	3 months	1918	1921	1922	1919
6	Estimated leakage per minute	50 gallons	30 gallons	20 gallons	5 gallons	10 gallons	20 gallons	20 gallons	30 gallons	10 gallons	10 gallons
7	When did disentegration start?	2 years	2 years	2 years	At once	At once	3 months	3 months	1 year	7 years	2 years
8	Mixture of concrete	1:2:4	1:2:4	1:2:4	1:2:5	1:2:5	1:2:4	1:2:4	1:2½:5	1:2½:5	1:2:4
9	Kind of aggregate	River sand and gravel	River sand and gravel	River sand and gravel	Gravel and crushed sandstone	Gravel, crushed limestone and sandstone	Crushed sandstone	Crushed sandstone	Broken stone and gravel	River sand and gravel	River sand and gravel
10	Grade of workmanship	Good	Good	Good	Fair	Good	Fair	Fair	Good	Good	Bad
11	Were water rings installed?	No	Yes	Yes	No	No	No	No	No	No	No
12	Was any grouting done?	No	No	No	Yes	No	No	No	Yes	No	Yes; not successful

TABLE II. DATA ON FAILURE OF CONCRETE SHAFT LININGS

	INSTALLATION	11	12	13	14	15	16	17	18	19	20
1	Date shaft was sunk	1917	1914	1914	1914	1914	1916	1918	1906	1907	19.1
2	Date lining was installed	1917	1914	1914	1914	1914	1916	1918	1919	1919	1914
3	Downcast or upcast	Downcast	Downcast	Downcast	Downcast	Downcast	Downcast	Downcast	Neutral	Neutral	Downcast
4	Is shaft wet?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
5	When did wetness start?	At once	1915	1915	1915	1915	1917	1919	1920	1920	1915
6	Estimated leakage per minute	10 gallons	30 gallons	30 gallons	20 gallons	20 gallons	30 gallons	20 gallons	....	....	Seepage
7	When did disintegration start?	At once	1917	1915	1915	1916	1917	1920	1922	1922	Uncertain
8	Mixture of concrete	1:2:4	1:3:4	1:3:4	1:3:4	1:3:4	1:3:4	1:3:4	1:2:4	1:2:4	1:2½:4
9	Kind of aggregate	Sand, gravel and crushed rock	River sand and gravel	River sand and gravel	River sand and gravel	River sand and gravel	River sand and gravel	River sand and gravel	Slag and sand	Slag and sand	Sandstone, gravel and sand
10	Grade of workmanship	Bad	Good	Good	Good	Good	Good	Good	Fair	Fair	Good
11	Were water rings installed?	No	No	No	No	No	No	No	No	No	No
12	Was any grouting done?	No	Yes	Yes	Yes	No	No	No	No	No	Yes
13	Was back drainage supplied?		Drain tile	Drain tile	Drain tile	Drain tile	Vertical pipes	Vertical pipes	Bleeder pipes	Bleeder pipes	No

TABLE III. DATA ON FAILURE OF CONCRETE SHAFT LININGS

INSTALLATION	21	22	23	24	25	26	27	28	29	30
1 Date shaft was sunk	1919	1909	1914	1919	1918	1911	1917	1916	1917	1918
2 Date lining was installed	1919	1910	1914	1919	1918	1911	1917	1916	1917	1918
3 Downcast or upcast	Downcast	Downcast	Downcast	Downcast	Downcast	Downcast	Downcast	Neutral	Downcast	Upcast
4 Is shaft wet?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
5 When did wetness start?	1920	1915	1917	1921	1919	1919	1920	1916	At once	At once
6 Estimated leakage per minute	30 gallons	30 gallons	30 gallons	20 gallons	30 gallons	50 gallons	10 gallons	30 gallons	Seepage	Seepage
7 When did disentegration start?	1922	1915	1918	1922	1920	1920	1920	1920	1918	1918
8 Mixture of concrete	1:2:4	1:2:4	1:2:4	1:2:4	1:2:4	1:2:5	1:2½:5	1:3:5	1:2:5	1:2:5
9 Kind of aggregate	Sand and gravel	Sand and gravel	Sand and gravel	Sand and gravel	Sand and gravel	Sand and gravel	Sand, gravel and crushed stone	Stone, sand and gravel	Crushed sandstone	Crushed sandstone
10 Grade of workmanship	Good	Good	Good	Good	Fair	Good	Good	Fair	Good	Good
11 Were water rings installed?	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No
12 Was any grouting done?	No	No	No	No	No	Yes	No	Yes	Yes	Yes
13 Was back drainage supplied?	No	No	No	No	No	No	Yes	Yes	No	No

pressure from the rock strata and prevent water from penetrating the concrete.

2. Mixture being uniformly as dense as possible, with complete protection from contact with both shaft and surface water until setting is complete.

3. Pouring the mixture in the forms with equipment that does not require water beyond that needed for proper mixing.

4. Making closure joints homogeneous with the rest of the lining.

5. Using grout only as an aid to sinking and not for permanently keeping strata water from contact with the lining.

6. More rigid inspection.

It is proposed to continue this study of concrete shaft linings in Pennsylvania and in other states as well.

DISCUSSION

C. H. DORSEY:* In the tabulation showing where the grouting was done, does it mean grouting during the sinking, or after the lining was completed?

N. G. ALFORD: During the sinking.

A. C. IRWIN:† It would be interesting to know the method of doing the grouting either while the shaft is being sunk or if grouting is attempted after the lining is in place. Unless grouting is done in such a way that there is resistance to the flowing out of the grout through the fissures, it can not possibly be effective. But if there is a reaction against it so that high pressure can be developed, remarkable results may be achieved. The answer to the question as to just how grouting is done in cases of shaft lining will usually also be the answer as to why the work is not effective. Sometimes conditions are so unfavorable as to make satisfactory results impossible.

N. G. ALFORD: That is a question we can not answer without making a particular study of each one of those cases and getting a special report from either the company that had the work done or the contractor who did the work. No doubt there are two or three contractors present who can tell us something about these installations, as I think several of them are familiar with the cases that have been mentioned.

H. N. EAVENSON:‡ I do not know that I can add very much to what has been said. One of the principal determining factors in what happens to a concrete lining is freezing, because farther south, in West Virginia, there have been no reports of trouble with concrete lining and, while we are doubtful whether the situation is as good as this, there have been no cases of lining failure discovered so far. In southern West Virginia there are probably a dozen concrete-lined shafts. There have been perhaps more failures in the Somerset County section in proportion to the number of shafts than there are

*Treasurer, R. G. Johnson Co., Pittsburgh.
†Manager, Railways Bureau, Portland Cement Association, Chicago.
‡Consulting Engineer, Howard N. Eavenson & Associates, Pittsburgh.

immediately around Pittsburgh, and the climate there is considerably colder than it is here. My opinion is that, if a concrete lining is put in without greater protection than is necessary for a timber lining, it will not last any great length of time, and I have very serious doubts if any concrete lining yet put in a coal shaft will last as long as a good timber lining, although perhaps it is too early to tell that yet. The oldest lining I know of is 22 years old, and that particular shaft was abandoned for hoisting and allowed to fill up about sixteen years ago, so that we do not know now in what shape the lining is. This shaft also was in a much milder climate than around Pittsburgh.

It seems to me that there are three problems to be considered:

1. Freezing.
2. Drainage of water from the back of the linings.
3. Probable effect of the water pressure on the concrete.

Whether this last item amounts to very much or not I do not know, but it would appear to be of considerable importance. Undoubtedly, freezing is a very large factor, although in a number of the shafts where failure was reported the ventilation was neutral and three or four of them were upcast shafts where the temperature was probably not under 50 degrees, so that freezing could have had little effect on these.

I have seen one or two cases where grouting apparently resulted in chasing the water from one part of the lining to another, and perhaps two years ago I saw a shaft lining in West Virginia in which the shaft was grouted as it was sunk, and apparently a good job was made. The water, however, came out at one place, and after grouting it there it broke out in another place, and I have very serious doubts if that shaft lining will last over five years.

Someone asked about a shaft at Welch, W. Va. There are two shaft plants there—one sunk about 1904 or 1905, perhaps not quite three-quarters of a mile from another one which was sunk in 1914 or 1915. I have been told that the grout in the second shaft came through in the water wells of the town about 3000 feet away and stopped the flow in these wells; and I have been told by one of our members that he actually saw the cement in a pillar fall in the first shaft at a point that was more than a quarter of a mile from the second shaft. There was one place where over 1600 bags of cement were put in before the water was shut off at all.

We know nothing about the results of the linings of this second plant, because the main hoist has never yet been used as a hoisting shaft and there is no air circulating in it, so that we can not tell whether the temperature has had any effect on it or not.

In my opinion (while it apparently is a step backward), for economic reasons we shall have to go back to timber or else spend more money for a brick lining, or something of that sort, unless we can get a more satisfactory concrete lining than has yet been secured.

F. A. McDonald:* One of the shafts shown on the screen, and described by the speaker, was the main hoisting shaft at our No. 2 mine; we also have four or five other concrete-lined shafts, with only one of which we have, thus far, had similar trouble. This shaft was a small, circular air-shaft used as an intake, and was repaired with concrete, and at the present time it is in fairly good shape. I was going to ask whether any study had been made of concrete-lined slopes to determine whether they were subject to the same deterioration in this latitude as has been found in many of the concrete-lined shafts. About 1903, at Bridgeport, Pa. (near Brownsville), I sank two shafts and lined them with concrete, the depth of the shafts being about 90 feet. One was an upcast air-shaft, the other (the main hoisting shaft) being an intake. Near these I drove a long slope to the coal, the sides and arch of the slope being composed of concrete. The lining of the shafts was somewhat thicker and more massive than it is now customary to use. The reason these were made heavy was because they were at the base of the river hill and the soil above the rock was very soft and we were unable to timber the large shaft in the usual manner until we reached the rock stratum, but had to build a lining in a form on a shoe on the surface, which sank of its own weight when the soil was undermined from the shoe, until it reached rock sufficiently hard to hold the shell. I have never heard of any failure either in these shafts or in the slope.

I think it is very true that while concrete is being put in place, and until it is at least partially set, it should be protected as far as possible from any water except that necessary to make the concrete of the proper consistency. Of course, the method of placing the concrete in position has a great influence on the character of the finished work,

*General Superintendent and Chief Engineer, National Mining Co., Morgan, Pa.

for you may use the best of materials in the proper proportions and have them well mixed, but if they are handled roughly and dropped for long distances, there is a tendency for the different ingredients to separate and form a porous concrete.

We have another concrete-lined shaft at our No. 2 mine, one side of which is equipped with a single-cage hoist and is a downcast, the other side being an upcast for the fan; also, at our No. 3 mine, we have a shaft which has an upcast on one side and a downcast on the other; also a downcast main shaft, none of which, thus far, has shown signs of distress, but these last three are comparatively new shafts. When the large shaft, shown on the screen, began to show excessive moisture, we drilled drainage holes outside the lining down into the mine, with the idea of relieving the water pressure behind it, and, for a time, it seemed to do some good.

If we are still to use concrete lining in mine shafts in this latitude, in my opinion we must exercise extraordinary vigilance, being sure that only the very best and cleanest of materials are used, that the proportions are correct, that proper attention is paid to the placing of the concrete, that the strata are well drained so as not to add excessive water to the mixture and that the work is done at a season of the year when it will not be subject to extreme cold. If these precautions are taken, I believe that concrete linings will prove successful.

N. F. Hopkins: How far away from the shaft were those holes drilled?

F. A. McDonald: Just as near the shaft as we could get the machine; I think probably about five or six feet from the face of the shaft. We wanted to get back a little so that the strata would be porous and not filled with cement which might have permeated from the concrete lining.

N. G. Alford: I might say that in the course of gathering this information about concrete shaft linings we incidentally picked up data on two concrete-lined slopes, both of which had given satisfactory service up to the date of our inquiry. I have forgotten just how long they had been installed when we asked about them.

F. A. McDonald: The one I spoke of was put down in 1903 or 1904.

H. M. Ernst:* If your trouble were due to water pressure back of the lining you would not find curtain-wall failures.

N. G. Alford: I am not qualified to answer that question, but in the case I mentioned it is probable that the curtain-wall was too thin. It was only four inches thick. If the thickness had been increased 50 to 75 per cent. the result might have been different.

C. H. Dorsey: I know of a case where a curtain-wall 12 inches thick constructed in 1917 failed almost absolutely and was replaced this year. This shaft was practically dry when I saw it this summer.

N. F. Hopkins: I think the failure of these curtain-walls and the condition of the concrete around the buntons were both due to temperature stresses. Concrete and steel have about the same coefficient of expansion. The shaft or foundation is rigid. It seems to me that the temperature must place some pretty severe strains on those curtain-walls, and that, rather than water or faulty cement, is possibly the reason for the failure.

N. G. Alford: No statement was made in the paper that faulty cement was used in any of this work. It was all good, standard cement in each case.

N. F. Hopkins: Don't you think that is a possible reason?

N. G. Alford: I should like to ask Mr. Dorsey what mixture he used in his 12-inch wall.

C. H. Dorsey: The proportions were 1 : 2 : 4. The 12-inch wall that failed was downcast on one side and upcast on the other, and was subjected to quite a wide variation in temperature.

*General Superintendent, Pittsburgh Terminal Coal Corporation, Pittsburgh.

F. A. McDONALD: In discussing the cause of the disintegration of this lining, we observed that it was greatest at the lower portion of the shaft; we also noted that our cars, not being water-tight and the coal often being wet, would, when the cages started from the bottom, throw a great quantity of water against the lining, and we wondered if this water might not be absorbed, even to a small extent, by the lining, then become frozen and thus cause disintegration from the face of the shaft.

N. F. HOPKINS: Was that sulphur water, Mr. McDonald?

F. A. McDONALD: Yes.

F. R. McMILLAN:* The discussion to-night is very interesting to me, for during the past 15 months I have made some investigation of disintegrated concrete for a committee of the American Concrete Institute. The committee I refer to is the Committee on Destructive Agents and Protective Treatments, of which Mr. M. M. Upson is chairman and of which Mr. P. J. Freeman, of the Bureau of Tests of Allegheny County, who is here to-night, is a member. It happened to be my part in the committee work to make an extensive field survey of structures which showed signs of disintegration and, as far as was possible, to determine the causes for the conditions found. Some of the observations made during this study and some of the conclusions formulated may be of interest in connection with the subject under discussion.

In the paper of the evening, it appears that failures have been reported in about 30 per cent. of shaft linings examined. Our studies indicate that, in so far as the number of structures affected is concerned, this mortality is probably no higher than in other structures exposed to water, although the extent of failure in mine shafts, it would appear from the paper and the discussion, is somewhat greater. This may possibly be due to the high water pressures encountered in mine shafts which are no doubt very much greater than those in the ordinary exposed structure.

There are a number of statements in Mr. Alford's paper that are supported fully by the results of our investigation, particularly the

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conclusions. It may not be out of place to point out the agreement between these and the findings of the committee.

1. Sufficient drainage should be provided to relieve natural water pressure. (Similar drainage would have prevented the failure of a good many of the structures that we examined. The greatest cause of disintegration was found to be the freezing of water within the concrete mass.)

2. Mixtures should be uniform, as dense as possible, with complete protection from water until setting is completed. (That is fundamentally true in the light of our studies.)

3. A mixture not wetter than needed for the proper manipulation should be used. (We agree with that; in fact, our studies indicate that the use of excess mixing water is one of the principal causes of porous concrete.)

4. The importance of making closer joints between sections of the lining. (In practically all of the field structures showing disintegration which we examined, water came through the joints between the various sections. Water must be kept from coming through the joints if disintegration is to be avoided.)

5. Grout should be used as an aid to sinking and not to keep water from contact with the lining. (This latter should be accomplished through vents and water rings and thus prevent the accumulation of a head behind the structures. We have no parallel cases in ordinary structures; but keeping water out of the concrete will prolong the life of the structure.)

6. More rigid inspection. (Our studies show the importance of this. The poor condition of many structures can be traced directly to lack of proper control of the making and placing of the concrete.)

Our committee has summarized its findings in two fundamental conclusions—first, that practically 90 per cent. of the disintegration examined was due to the effect of frost and moisture on porous concrete; second, that porous concrete was largely the result of insufficient cementing material, wrong proportioning, careless workmanship or improper manipulation.

The requirements of an impervious concrete are that the aggregate particles must be thoroughly surrounded and the voids completely filled with a cement paste which is itself impermeable. This means that there must be enough cement to fill the voids and that the quan-

tity of water used shall not be such as to give a porous paste. Water in excess of the minimum requirements for hydration and workability will later evaporate, leaving pores and water passages.

Having an impermeable paste in sufficient quantity to fill the voids, the next and most important step in obtaining water-tight concrete is the manipulation of the mass so that there will be no segregation or honeycombing. The manipulation will be easier and the danger of honeycombing less in a mixture in which the coarse particles are not too greatly in excess of the fine.

It is quite a common practice to use fine and coarse aggregates in the proportion of 1 to 2, as in 1 : 2 : 4 concrete. With some materials this will give a workable mix, provided the quantities called for are actually used. As it usually works out with loose measurement of moist aggregates, the sand is bulked from 20 to 30 per cent., so that the actual mix may be about 1 : 1½ : 4. This will be a harsh mix, difficult to place and will leave a honeycombed or porous mass. If used with excess water, such a mix will segregate badly, making the results very much worse. With materials of good grading carefully placed, a 1 : 2 : 4 mixture on the basis of dry compact measurement will give a wall which will be practically water-tight. But only under the most favorable condition of materials and workmanship can a 1 : 2½ : 5 concrete (dry compact measurement) be expected to give any degree of water-tightness. It is safer practice to keep down the proportion of coarse material and use mixes rich enough in cement so that the mass can be puddled easily in the forms without segregation or the accumulation of water on the surface.

To summarize, it seems to me the problem of mine-shaft linings is exactly the same as the one encountered in ordinary structures for water-supply, for irrigation, dams, retaining walls, bridge piers, etc.—that is, to make concrete that is impervious. And the problem of making impervious concrete is to have a dense mass—that is, an aggregate combination in which all the voids are thoroughly filled with a cement paste of low water-ratio.

CARL WEBER:* Mr. Alford's most interesting lecture is perhaps of special interest to me for the reason that I have also inspected a large number of defective mine-shaft linings not only of reinforced

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concrete construction, but also shafts with brick, masonry, and timber linings, not only in the United States, but also in Canada and in different European countries, as for instance, in Germany, France and Belgium. In examining these mine shafts I am somewhat on the other side of the fence. The purpose of all of my mine-shaft inspection work is not only to analyze the defects, but also to do the necessary repair and protection work mostly on a contract basis. I think it might be of interest to you to hear from me a few words on the subject and also a few remarks regarding European practice.

A statement was made here this evening that we will perhaps come back to the timber shaft or to brick lining. The fact is, however, that there is no better shaft protection than the concrete lining; but we are making many mistakes here, mostly in the direction of economy. The principal question to us here is how cheaply we can do the work. Most of these reinforced-concrete shaft linings that have failed (and I have seen a good many of them) have been too light. In shafts 600 or 700 feet deep, a thickness of 6 to 10 inches is not enough. There are only a few concrete shafts in Europe that are not at least 16 to 24 inches thick. Another European practice is that of making the shafts in circular form. American mining shafts are nearly all of rectangular form. We had to make the shafts rectangular for timber linings, and when we came to concrete we simply kept on making them rectangular. Drains and weep holes will close up, and this results, at least to some extent, in hydrostatic pressure. The circular form of construction will, of course, withstand such pressures better than a rectangular form.

During the many years of our experience with such work we have developed several methods for repairs to shafts. Usually we are called upon to repair the disintegrated concrete surfaces by cement-gun methods. It is evident, however, that just to put 1½ or 2 inches of gunite on the interior surface is not a permanent repair because the freezing of the water behind the gunite or mortar surface will cause its loosening and peeling off in the next winter season. The only permanent repair possible is to remove the water-logged condition of the concrete by grouting. Quite an advance has been made by us in plastic mortar grouting. Older grouting methods which only inject a practically liquid material in the grouting holes in order to stop leakage through the masonry are entirely insufficient. If you want to do

successful grouting you must use a plastic mortar of about such a consistency as the bricklayer uses on the trowel. We have successfully grouted water-pressure tunnels for hydro-electric power-plants in Switzerland with either plastic cement mortar or our special clay compounds. We are using these methods also in mines where ordinary cement grouting would be impossible on account of salt or sulphur in the water. We frequently use a clay compound and mix it with the mine water so we have the same water condition, which is of special importance in salt and potash mines where fresh water in the grout would do much harm. Our system of clay grouting has been used right here near Pittsburgh, in the American Zinc and Metal Company's coal-mine at the Langeloth mine at Slovan, Pa. The concrete, timber-lined mine slope was waterproofed by filling the water-bearing fissures and cavities by our intrusion method with clay compounds, taking the clay right from the side of the hill at the slope portal. I have reports from the superintendent of the Langeloth mine that during the last two winters (the work was done two years ago) all interference by ice was completely eliminated.

European practice is to avoid leading any water from the shaft into the mine, and to build the shafts strong enough with thicker concrete to withstand water pressure, and then to shut off absolutely any surface or ground water from behind it. This can always be done. We have done it in mine shafts 2400 feet deep and in very bad ground. Usually this is eventually much cheaper than the additional continuous cost of pumping.

The gentlemen from the Portland Cement Association emphasized the use of rich mixtures without any waterproofing, and that is, as a rule, a good point. But in mine shafts where the work has to be done under extreme difficulties, and where you can not always have perfect inspection of the work under ground, it is a mere matter of protection to use an integral waterproofing such as "Fluxite." This gives an additional assurance of obtaining an impervious concrete, and that is of prime importance in all shaft-lining work.

Here to-night we have seen that some of the mine shafts start to disintegrate in one or two years. It takes, of course, time for the water, frost and air to act, but one factor that has not been sufficiently mentioned here is that a good many of the mines have water contaminated with sulphur, salt and other substances that are enemies to the

concrete. If they once get a start at the concrete there is nothing to stop its destruction. The lining of mine shafts is a very important subject and there are many things that I could point out here if I had more time at my disposal. There can be no question, however, that concrete gives by far the best shaft lining if properly built. On account of the ground and hydrostatic pressures against the shaft lining, a circular shaft has many advantages. I think it is the best form in all respects. I have seen concrete shafts, now over forty years old, and they are as good to-day as on the day they were completed.

European construction practice is different from ours in many ways. In order to save on workmanship, because labor is very expensive, we are inclined to waste cement by using mixtures which are too rich and too wet, and then placing concrete in the forms by shooting it in. For mine-shaft work, that is all wrong. As a matter of precaution we should use less water and always use some waterproofing compound as a lubricating medium if for no other purpose. Even if it is perhaps not necessary, it is an inexpensive matter and provides a factor of safety that we can not afford to neglect. It was said here to-night that the proportion of about 30 to 35 per cent. failure is what can be normally expected in concrete work. We, as concrete engineers, should hide our faces in shame if that is correct. We are now building a good many concrete structures that we surely must expect to stand 40 or 50 years and then be just as sound and solid as when they were completed. If we could not build concrete structures more than 65 or 70 per cent. dependable, whether mine shaft or outside structures, we should not induce anyone to use concrete for construction purposes. It is true that there is still some poor concrete work being done by inexperienced workmen, but, as a rule, concrete work is now properly designed and if intrusted to the care of a reputable contracting firm there is no reason why the percentage of failures can not be reduced to a negligible quantity. Do not forget, however, that we have also occasional failures of steel, brick, and stone construction. There is nothing in this world that is 100 per cent. fool-proof.

T. P. Watson:* We have probably had more experience than any other organization in the actual field design of concrete mixtures using local Allegheny River aggregates.

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The arbitrary concrete mixtures referred to in this paper as 1 : 2 : 5, 1 : 3 : 5 and 1 : 2 : 4 are fundamentally wrong if local river aggregates are used. Assuming that fine Allegheny River sand and commercial-size gravel ⅝ to 1½ inches are used, and that aggregates are measured by the usual loose-volume method, the leanest mixture should not be more than 1 : 2.5 : 3.5 where severe climatic conditions are encountered as in work of this character.

I would suggest that a mixture of 1 : 2 : 3 be used from the ground level to a point where experience has shown marked disintegration from frost action.

If admixtures are used, these proportions should be different.

If different sized fine or coarse aggregates are used, these proportions should be materially changed.

The reason for suggesting these richer mixtures is, that we have found that in order to obtain a concrete of approximate maximum density with a workability sufficiently plastic to flow in thin sections and properly embed the steel reinforcement, the use of these mixtures is necessary to avoid the use of excessive mixing water in the concrete, thereby preventing the formation of laitance and saturation of the concrete, the latter being the one most easily remedied cause of concrete disintegration.

The manufacture of durable concrete in work of this character requires a much higher grade of supervision or craftsmanship than has usually been obtained, and the following brief outline of suggestions may be used to advantage:

1. Evenly graded aggregates should be used at all times.
2. The proportions of aggregates should be carefully measured for each batch and especial attention paid to the quantity of mixing water used. Only enough water should be used to permit the concrete to be placed in its final position as a homogeneous mass.
3. Concrete for this type of work should be mixed a minimum interval of two minutes after all the ingredients are in the mixer.
4. Strong water-tight forms, properly braced to prevent movement of any kind, should be used.
5. Forms should remain in place at least five days, and longer if possible, to permit the proper curing of the concrete. If the forms are removed sooner, some method of keeping the surface of the concrete moist should be devised to avoid too rapid evaporation of the water

in the concrete, which prevents the proper hydration of the cement. If precautions regarding curing are not taken, and freshly poured concrete is permanently exposed to the air, small cracks will appear on the surface of the concrete, thereby creating a starting point for the collection of moisture and subsequent frost action.

6. Open chutes should be avoided whenever possible and trunk chutes used instead.

I agree with the preceding speaker that the wall sections of the shafts covered in this paper are too thin, and a design of a minimum thickness of 18 inches, or preferably two feet in the upper section where seepage, ground water and frost action are encountered, would justify the increased cost by greatly adding to the durability of the lining.

What is the general practice in constructing these shaft linings as it applies to the height of the vertical sections poured at one time?

C. H. Dorsey: Five or six feet.

T. P. Watson: How are the sections poured?

C. H. Dorsey: The concrete is discharged from the mixer into a shaft bucket and lowered into the form. The bucket is dumped into a chute which carries the concrete back of the form.

T. P. Watson: How is the concrete transported to the form?

C. H. Dorsey: It is dumped from the center of the shaft to the furthermost edge of it.

T. P. Watson: Then the concrete is quite sloppy?

C. H. Dorsey: Yes, it is. It is hard to get them to reduce the water.

T. P. Watson: One of the preceding speakers referred to the possibility of using slope arch construction instead of vertical shafts to avoid the troubles that have been encountered by disintegrating vertical shaft linings. In this connection we have just completed, at

a very considerable expense, repairs of a concrete-lined tunnel on the Allegheny Division, about one hundred miles north of this city.

This tunnel, which is 2700 feet long and with a clear span of 30 feet, is lined throughout with concrete except 120 degrees of the semi-circular arch, which was faced with one layer of brick as a protection against the blast of the locomotives. The disintegration of the concrete extends 800 feet from the north portal and 400 feet from the south portal. The intermediate 1500 feet of the lining is in good condition. The disintegration was greatest near the portals and gradually became less as the distance from the portals increased. Strange as it may seem, the disintegration was just as marked at points where the natural rock was absolutely dry as where there was marked seepage. The north end of this tunnel where the greatest disintegration occurred was practically dry, whereas in the south end, which was very wet due to leakage from fissures in the rock caused by a lateral movement superinduced by blasting, the concrete was in much better condition than that in the north end. The maximum disintegration occurred at the surface of the walls, and as the depth increased the disintegration became less. In some cases the disintegration extended to a depth of two feet, although the average was much less than this.

It is our conclusion that the deterioration of the concrete in this tunnel was caused by frost action upon concrete which contained an excessive quantity of mixing water. The latter premise is proved by the presence of thick laitance seams between undulating layers of concrete, and the frost theory is substantiated by observations on the concrete, brick-faced roof from which bricks were cut out at different points in the region of the side-wall failures, thus showing that there was no disintegration of this concrete, even though it was the same as that in the side walls, and of an inferior quality.

Two tunnels of the same type, 2400 and 3600 feet long respectively, were built on this same division at the same time and are in comparatively good condition. There has been some slight inconsequential disintegration at the construction joints in the vicinity of the portals in these tunnels.

N. F. Hopkins: Will Mr. Watson tell us how long it was after the installation before this disintegration started?

T. P. WATSON: About two years. The tunnels were concreted in 1914 and 1915.

N. G. ALFORD: Then why isn't the brick lining the solution of shaft failures?

T. P. WATSON: The facing with a good quality of brick laid in a workmanlike manner would prevent spalling, but would not eliminate the troublesome seepage and ice conditions.

Would it not be possible to build shaft linings in vertical sections 25 to 30 feet high? Concrete properly proportioned and properly placed in monolithic sections of heights up to 25 or 30 feet would remove the causes of the failures disclosed by this paper and the discussion.

C. H. DORSEY: No, it would not.

T. P. WATSON: We attempt to pour every concrete unit as a monolith not to exceed 30 feet in any dimension. We recently poured a pier 30 feet high, 5 feet wide at the top, 7½ feet wide at the base and 25 feet long, in 10 hours. It is a perfect piece of work.

A. C. IRWIN: I am very glad that Mr. Watson is present. Perhaps he has not had the proper introduction to this group. If, when you are lining mine shafts with concrete, you were to ask me what I would recommend in Pittsburgh, with all due respect to the experience, interest and knowledge of those who are responsible for this work, I could not think of a better thing to tell you than to get hold of Mr. Watson, of the Pennsylvania Railroad, tell him what your trouble is, and ask him what to do.

You all undoubtedly know where the Beck's Run and Street's Run bridges of the Pennsylvania Railroad are located. One of these bridges carries five tracks and the other four. In building these bridges, Mr. Watson used field control methods in making concrete, and when he refers to the quality of the concrete in these bridges he knows whereof he speaks, because he has compression tests on cylinders made from every part of these structures. Nothing went into those bridges that Mr. Watson did not know about. The best thing

you can do is to go out and look at them and see what you think of them. I am sorry that Mr. Watson has not had a paper before this group to tell you just what he did. He has told it in several places—before the Philadelphia Section of the American Society of Civil Engineers, the convention of the American Concrete Institute in Chicago, in Montreal, and other places, and I have heard the comment that Mr. Watson's explanation of the field control of concrete was very clear and lucid, indeed. In fact, I can testify to this myself.

Mr. Alford has presented the results of an investigation of 106 concrete mine-shaft linings, and of these all but 30 were in fairly good condition. The important thing is that some of them are in excellent condition. What has been done once can be done again. What has been done right once should always be done that way, and can be. That is simple logic. The wonder is that 65 or 70 of those mine shafts are in good shape—not that there are 30 failures. When we note the results of tests of the effects of water and the water-cement ratio on the strength of concrete, there will be no further question as to what was wrong.

I do not think a 1 : 2 : 5 mixture is, in general, concrete, because it is a practical certainty that there will not be enough mortar to make a plastic, workable mix, especially if the sand is damp. Furthermore, you can take a 1 : 2 : 4 mixture and, by the mere process of changing the water, get a variation of 100 per cent. in strength. There are four things in concrete—stone, sand, cement and water. If there is not enough cement mortar to fill the voids of the coarse aggregate and to take care of imperfections of mixing, transporting and working into the forms and around the reinforcement, so that an excess of mortar will be present to fill the voids of the stone, you do not have concrete. Stony places, known as "honeycomb," are certain with such a mixture. There is no possible chance of getting water-tight concrete over large areas with an under-sanded mix.

The matter of concrete linings for mine shafts is one of manipulation. You must have enough inspection to get proper proportions and to see to it that the concrete goes into place properly. Impervious concrete can be obtained regularly, even under the rather difficult conditions of mine-shaft lining.

I am satisfied that if detailed information about the materials and methods were available for each of the cases of unsatisfactory

results, the cause would be apparent. An arbitrary mix, as 1 : 2 : 4 or leaner, with the water content entirely optional and no correction for bulking of fine aggregate, can be expected to give uniformly satisfactory concrete only in those cases in which the contractor violates the fixed proportions according to his experience in producing workable concrete, and keeps the water content to a minimum.

If I were to lay down rules for concrete shaft lining, they would be about as follows:

1. Keep down the water content to about 6½ gallons per sack of cement. This includes the water in the aggregate.

2. Avoid under-sanded mixes by correcting for the bulking of fine aggregate, due to its moisture content. Secure always a consistency which will permit puddling.

3. Avoid segregation in placing.

4. Mix at least two minutes in a batch mixer.

5. Make sure that there is not a layer of laitance at fill planes. Keeping down the water content will do much to prevent laitance.

6. Make the lining sufficiently thick, providing reinforcement if necessary, to hold the water pressure, or cut down the pressure by drainage or by grouting.

F. A. McDONALD: The speaker stated that we made repairs to the lining in one shaft with brick. Some of you know that the United States Steel Corporation, of which our company is a part, is a large manufacturer of cement, and, naturally, I am very sympathetic and partial to concrete construction when it can be properly used; however, as this mine, which produces from 2000 to 3000 tons a day, was in continuous operation and we were desirous of making our repairs without interruption to mining, the use of brick was much more practical in this instance, for we were able to use the cages during the night, placing additional scaffolding in the air compartment and building four or five feet per night, and be ready for operation at 7 o'clock in the morning. The brick used was a large-sized, vitrified paver, very hard and practically non-absorbent. The large size was used to reduce the number of joints as much as possible. The brick was carefully laid in cement mortar and the space from the brick back to the wall was filled in with spalls and mortar; also, very careful attention was paid to draining wet spots in the shaft. On

account of the small quantity of work being done each night, our inspector, who was on duty during all the working hours, was able to keep a very careful check on the character of the work and the material being used.

W. A. Weldin:* I note that in Mr. Alford's list of shafts, No. 3, No. 10 and No. 30 are upcast. It is seen that in No. 30 wetness started at once with seepage; also that the mixture was a lean one, and the aggregate crushed sandstone. It is mentioned that the workmanship of No. 10 was bad. This leaves No. 3 as the only upcast shaft which is not open to suspicion as to workmanship.

There are also three shafts listed as neutral, but in these cases the workmanship is noted as fair.

In view of the difficulties of casting good concrete under shaft-sinking conditions, and in view of our recent experience as to the difficulty of getting high-grade concrete for such conditions even in the open, it is a fair presumption that workmanship which would be fair for shaft-sinking conditions would be rated as poor for pavements, for instance.

It thus appears that, narrowing the study down by eliminating five shafts of the remaining 25, only one upcast shaft has failed. Each of the 24 failures of downcast shafts, whatever may have been their cause, must have been matched by an upcast shaft which did not fail. This for the reason that shafts are almost invariably constructed in pairs. It is to be noted also that these pairs were probably constructed at exactly the same time, of the same materials, by the same contractor, and that, therefore, we have a condition of striking contrast in which the only difference in the two classes is that of temperature.

This seems to narrow the cause right down to freezing. If there is any other cause, such as hydrostatic pressure, it would operate equally on upcast and downcast shafts. There is another striking feature of the tabulation. With very few exceptions, and some of these exceptions open to suspicion as to workmanship, the failures seem to be of shafts built since 1915, approximately the date when grouting began to be substituted for drainage.

While the reports are not complete, it appears upon inquiry that a number of shafts with which the speaker is familiar, constructed

*Blum, Weldin & Co., Pittsburgh.

prior to that date, and the design of which was built primarily around the idea of drainage behind the lining, have stood up well. This seems to be consistent with the theory that the trouble comes from freezing of water percolating through the linings. If this water is caught and drained down behind the lining, of course, it does not percolate and freeze.

In other cases, disintegration has been found to be below the water rings or in portions of shafts which it was not considered necessary to drain.

I think Mr. Watson's remarks as to experience with design of mixtures, and Mr. Irwin's remarks as to the effect of the water-cement ratio, and other elements so thoroughly investigated by the Lewis Institute, are very pertinent here. I fear that in shaft linings we have been using mixtures too lean, not properly placed, and too wet. This refers particularly to the practice of a few years ago.

I think the history of concrete shaft lining will be somewhat similar to that of concrete roads. The early roads, or many of them, cracked and disintegrated under traffic, but—thanks to the investigations of numerous agencies, such as the Institute already referred to, the United States Bureau of Roads, the state of Illinois and a number of other agencies—road slabs are now built which inspire full confidence on the part of the public.

The same principles as to design of mixture, mixing, placing, and control of water, as well as provision for temperature changes and other stresses, combined with thorough drainage, I am sure will produce concrete shaft linings just as successful and durable as concrete roads.

N. G. Alford: Mr. Duckwall is here from Scottdale and he can tell us about some of the earlier concrete linings his company made.

A. E. Duckwall:* The Frick Coke Company has a total of 37 shafts lined with concrete. Of that number there are 19 which are downcast shafts and 18 which are upcast. We have not experienced difficulty with the upcast shafts. They are occasionally wet, but not as bad as the others. Due to the fact that they do not freeze,

*H. C. Frick Coke Co., Scottdale, Pa.

they do not bother us much, but in the 19 downcast shafts we have had eight failures. Six of them were prior to 1921. Our earlier shafts caused the trouble. Since then we have had two that have been wet. There is not much to add to what has been said. I think the gentleman who drew the parallel to the concrete road took an excellent example, and the ingenuity that solved the road problem can solve the mine-shaft problem. We are very favorable to concrete shafts. We think that relining a timber shaft with concrete is the thing to do. It costs about 15 per cent. more in first cost than to retimber it, but our experience is that we get only about ten years out of timber and we get more than that out of concrete. We have a concrete shaft installed in 1908.

There has been quite a lot of comment on the amount of water, and I agree with the speaker that this is the crux of the whole situation. In the latest shafts concreted we used a material (put out by a Pittsburgh concern) called "Fluxite," which makes the aggregate more plastic so you can get along with considerably less water. In the past we used 35 to 40 gallons of water per yard, and we are now getting along with 25 to 30. That is one reason we are getting better concrete—we are using less water and mixing it longer.

E. T. Gott:* There is very little I can add to what has already been said. We are trying to overcome these difficulties as we find them, each job presenting new and often difficult conditions. The old mixtures of 1 : 2 : 5 and 1 : 3 : 5 have been abandoned and we are coming to the use of 1 : 1½ : 3 and 1 : 2 : 3. The water is the thing we have to fight. If it is walled up back of the lining with no relief, it will certainly find its way through, and eventually break it down. Where the concrete is placed and handled properly, and your lining well drained, you should have no trouble.

N. F. Hopkins: Would it cost more to place the dry concrete?

E. T. Gott: Not much.

C. H. Dorsey: We are of the opinion that the brick lining offers an easy solution to the failures in concrete. With brick you

*Vice-President, Dravo Contracting Co., Pittsburgh.

have at the outset an impervious surface. If you can save the surface of the lining you save the entire lining. The area that will fail in a brick lining is the joints, but this area is very much smaller than the area that is impervious. The quality of the mortar in the joints in a brick lining can be controlled much more easily than the quality of concrete in a lining. The cost of a brick lining is greater than that of concrete, but I do not believe it will cost more than 50 to 75 per cent. more and I believe it will give very much longer life.

H. M. Ernst: I do not believe it is a matter of water pressure behind the concrete. The worst case I have seen of concrete failure was that of 18-inch supporting pillars in a shaft. You could knock the pillar down if it were not for the reinforcement. There is certainly no water pressure there. I am convinced the trouble is mostly in the density of the concrete. If you can control the concrete as well as you control the mortar in the brick joint, concrete would do just as well as brick.

N. F. Hopkins: We all know that concrete expands and contracts with changes in temperature. A shaft lining is surrounded by an unyielding backing of nearly uniform temperature, while the face of the lining is subjected to changes of temperature, perhaps as much as 60 degrees F.

Let us see what happens to a beam of concrete rigidly fastened at both ends, and subjected to changes of temperature amounting to 60 degrees F. The modulus of expansion of concrete is 0.000006 per degree F.; therefore, for 60 degrees the expansion is 0.00036 of the length. If the modulus of elasticity of concrete be assumed as 3,000,000, the stress in the concrete is then 1080 pounds per square inch.

Unless there is sufficient reinforcement, it is quite probable that such a beam would fail when the temperature drops 60 degrees. This would explain the failure of insufficiently reinforced curtain-walls when unaffected by water.

Now let us examine the concrete lining around the shaft. It is put in at a temperature somewhere around 70 degrees F., and, if the temperature of the air down the shaft the next winter is 10 degrees, it would seem to be possible for the tensile strength of the concrete

to be exceeded and incipient rupture to occur on the face. Percolation of water in even small quantities with the subsequent freezing might cause these already fractured pieces to spall off.

In a recent paper before this Society, Mr. Goldbeck, of the United States Bureau of Highways, pointed out how important it is in highway work to place the concrete highway slab on as smooth a subgrade as possible in order that the slab will have a chance to slide over the surface when expanded or contracted by changes in temperature. While mine shafts are not subjected to as great changes in temperature as are highways, a shaft lining anchored to the rough rock backing has no chance to slide, and, therefore, there must be considerable stress in the concrete, due to a drop in temperature of, say, 60 degrees.

It would seem advisable to set steel buntons into recesses in the wall, and not attempt to anchor them firmly into the concrete; also to reinforce all concrete curtain walls heavily, and it may be that the placing of reinforcing material close to the face of the lining, to take up the temperature stresses, may be of help.

Another precaution which might be taken, but which would add considerably to the cost, would be to put in a preliminary lining as the shaft is sunk; then a second lining inside of the first lining with membrane waterproofing between the two linings. This second lining would then be elastic and capable of expanding and contracting with changes of temperature. It would be necessary to support this interior lining at intervals in deep shafts.

N. G. Alford: I think that would be well worth while thinking about; it is a point that has not been given a great deal of attention so far.

N. F. Hopkins: In a concrete bridge, the changes in temperature are a considerable factor, but the arch has a chance to rise and fall with the temperature.

C. H. Dorsey: Couldn't that be taken care of in a shaft by reinforcement?

N. F. Hopkins: No, I do not think it could be.

A. F. BROSKY:* Are not other structures subject to the same expansion and contraction as shaft linings?

N. F. HOPKINS: They put expansion joints in roads. A concrete arch bridge expands and contracts. In high arch bridges there is quite a perceptible rise with rise of temperature.

SION B. SMITH:† The shaft, being in the ground, is not subject to wide enough variation of temperature to make this a factor. When they first began to weld street-car rails they were afraid they would kink in hot weather from the expansion, but it was found that the web and base of the rail being under ground the rail kept approximately the temperature of the ground and there was not enough expansion in hot weather to make the rail kink.

JOHN M. RICE:‡ I have had considerable experience with the deterioration of concrete and brick structures used in water-works systems, water reservoirs, filters, and dams, and know of some excellent results being secured by the use of the cement gun and gunite. Is there anyone here who has had experience with the use of the cement gun where the lining of concrete mine shafts has disintegrated and, if there is, will he please tell us what the results have been.

CARL WEBER: The cement gun is quite extensively used. It is indeed the only safe method for concrete surface repairs for the reason that it is practically a welding together of the old and the new parts, if the work is done by experienced operators. Unfortunately, much of the work has been performed by inexperienced workers and, of course, the results were accordingly.

The old Belgian mining practice was to use brick linings. The area of percolation through good brick masonry is less, restricting it to practically the joints only; but it is, in fact, much more difficult to get good brickwork than good cement work for mine shafts. I do not believe that facing of concrete shaft walls with brick is good practice. You have the water-logged condition behind the brick even if it does not show on the surface. The principal thing is to remove the

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†Attorney, Pittsburgh.
‡Consulting Engineer, Pittsburgh.

water from the masonry, brick, or cement, and to have perfectly dense and dry walls that can not disintegrate.

C. H. DORSEY: Have those brick linings in Europe failed?

CARL WEBER: I have investigated a great many of them, and also railroad tunnels, and they are all subject to just the same troubles. Usually the walls are laid in rings to take up the pressure, and I have seen such linings where one or two rings had entirely fallen off in long sections. Brickwork is not the solution of the problem. Some of the old shafts are still very good, while some newer ones are badly in need of reconstruction. Much depends on the quality of the brick and mortar. If you have waterproof bricks and waterproof cement mortar you can, of course, do a good job.

M. E. HAWORTH:* We have only four concrete-lined shafts, but to date have experienced no serious difficulties and no failures. Considering concrete linings, however, it seems that the keynote has been reached in these discussions that if a dense concrete is properly placed and the water properly and effectively taken care of, a successful structure will be obtained.

There is one fundamental that has not been fully discussed—that is, the matter of stresses. It is possible under certain conditions, especially where the stratum is soft and approaches a quicksand in character, that a hydrostatic pressure may develop that will introduce stresses in the concrete higher than the ultimate for plain concrete, requiring a certain amount of reinforcing to prevent failure. In these cases, I believe a designer to be justified in assuming higher allowable stresses for both steel and concrete than in ordinary surface structures. For instance, the allowable for steel may be chosen as 30,000 to 35,000 pounds per square inch in tension and for concrete 2000 to 2500 pounds in compression. The assumption for hydrostatic pressures would be liberal and partially offset allowable units chosen. In any event, the design would be based on values that would insure against failure, only reducing the factor of safety. Since failures do not occur suddenly and no lives are placed in jeopardy, I believe a

*Chief Engineer, Hillman Coal & Coke Co., Pittsburgh.

designer justified in stressing the concrete and steel well toward the elastic limit rather than allowing a high factor of safety.

So far as obtaining dense concrete is concerned, there are two important factors to consider—the mix and the water. The aggregates and the cement are usually within the specification. A mix between 1 : 2 : 4 and 1 : 2 : 3 will usually insure a dense concrete, providing an excess of water is not used; and, if only sufficient water is used to obtain a plastic mass instead of a sloppy mass, a dense concrete will be obtained which, to insure a lasting job, must only be protected from ground water while setting.

I have seen many concrete structures poured and am quite satisfied that if more attention had been paid to the amount of water used in the concrete and in the cement grout placed under pressure for sealing off ground water, fewer failures would have occurred. Some engineers seem skeptical about the practicability of sealing off ground water, but I concur with Mr. Weber, that if the cement is placed in a plastic condition and the proper precautions taken, the sealing can be (and is being) effectively done.

When studying concrete under Prof. F. M. McCullough, of the Carnegie Institute of Technology, back in 1914, he stressed most thoroughly the seriousness of the use of excessive water in mixing, and the harmful effect on the concrete after aging. There is nothing new about the proper use of water; still we have many failures, unquestionably from the effect of neglect or ignorance on that point.

C. W. Gibbs:* Mr. Gott is engaged at the present time in sinking a shaft lined with concrete. The shaft has every appearance of being a pretty piece of work, and it would be interesting to know what methods they are using, what depth they are pouring, and anything he can can give us on the drainage question.

E. T. Gott: Harwick is using 1 : 1½ : 3 with river gravel and sand. Special attention is being paid to the water content in the mixture, and the matter of drainage in the shaft. We are trying to make a job and present indications are favorable. Whether it will be permanent or not, I can not say. We are making an effort to grout on the bottom as we encounter the water, but in this we have been only

*General Manager, Harwick Coal & Coke Co., Pittsburgh.

partially successful. There is still some water on the rib, and we are, therefore, not able to guarantee that this water will not find its way through the lining after the grouting is done, but we are trying to take care of it by back walling and drain-pipes, with grout later on. A distance of about 215 to 220 feet has been sunk to date. The shaft is to be 275 feet to the bottom of the coal. Particular attention is being paid to the lining, and if it does not stand up this time we will have to try some other scheme hereafter. We have had to contend with drilling and carrying down pilot holes ahead of the sinking and, if they show water, grouting is done on the bottom, in advance of the sinking, rather than let the water form on the rib, which we have found to be fatal in a rectangular shaft. There is some water now in the shaft, but not very much. I believe everything possible is being done to make this method of handling the water successful. There has been very little occasion to back wall a drain except at the closures. The section will not permit it. The shaft is rectangular, and we will undoubtedly have to pad the sides when grouting is done. Two or three places in the lining will have to be treated. We have tried to catch all of the water in the down holes and have gotten probably 95 per cent. of it in this way. Sealing off the other five per cent. now on the rib is the problem. The shaft lining is poured in five-foot sections as being the easiest spaded and most economically worked. It takes two hours to set and line a form and about as long to fill it, and we get from five to six forms a day.

For the closures between successive runs of lining, Mr. Rayburn has designed a pocket which is formed by a half box 6 by 12 inches, in the first form; and a corresponding half box 6 by 12 inches, at the closure of the next run. This 12-inch by 12-inch opening so formed around the shaft is to be filled with grout when the entire lining of the shaft is given its final treatment.

Carl Weber: One of the greatest problems to-day is the lining of water-pressure tunnels for hydro-electric plants. We have, for this special purpose, adopted two methods of plastic mortar grouting, which we named the low-pressure system and the high-pressure system. The low-pressure system is used to seal the open, water-bearing crevices between the tunnel lining and the rock surfaces; while the high-pressure system is used principally for the consolidation and

cementing of badly fissured rock around the tunnel. For this purpose, grout holes are drilled to intersect the rock fissures and then a plastic mortar is forced into the rock with sufficient pressure to fill the crevices completely with mortar. In this manner the rock is solidified and the dangers from uneven pressures are greatly reduced. Such grouting is, of course, a rather difficult operation, requiring great skill and experience in order to get the desired results. It is a special trade and should always be considered as such.

Grouting with a semi-liquid cement soup is almost entirely without results—it is usually nothing but a waste of time and money.

C. H. Dorsey: It is just a gamble at best, isn't it?

Carl Weber: No, it should not be. In mine-shaft repairs we usually start from the bottom up and make that shaft completely water-tight. We do not intend to let any water down to the bottom of the shaft, thus seeking to reduce the cost of pumping to the minimum. To lead the water behind the lining into the sump and then pump it to the surface is a wasteful method.

C. H. Dorsey: Why wouldn't it be better to grout ahead of the sinking of the shaft? If you grouted at high pressure each round that is drilled you would be sure to get every bit of the water. This would increase the cost of the operation, but with this critical situation wouldn't it pay?

Carl Weber: Unfortunately, it is, in most cases, not a question of what we can do, but of how cheaply we can do it. I may say that in my 30 years of engineering practice I have never been enabled to do a job as well as I knew it should be done. It is always a question of cost, time and other things that interfere with doing perfect work.

E. T. Gott: On the Detroit job, about 1200 feet deep, the only real success we had was the solid back walling of the entire section with steel sheeting of angle-and-plate construction. The other sections that were simply treated with corrugated iron were not water-tight. This shaft is for a salt mine and had to be dry. The immense

flows of water encountered in sinking were cut to seven gallons an hour by this method.

Does anyone have any information as to the grouting that was done on the Liberty Tunnel?

P. J. FREEMAN:* They forced grout in above the tunnel and, where there was ordinary water, I believe the tunnel is as dry as we can expect it to be, but there is a pond up on the hill above the south entrance of the tunnel which has never been drained. In spite of all the grouting (and they forced in enormous quantities of grout) there is still water coming down, to a certain extent. Under the circumstances, we feel that the tunnel is about as dry as we can expect it to be at the present time until that pond is drained.

We have some trouble with ice in the ventilation shafts. We do not know whether it is caused by water coming through the concrete shaft or by condensation from the gases, but icicles form under certain weather conditions. We have placed in the shaft a set of grids which will catch the ice, and have also installed ladders which will enable us to examine the inside of these shafts this winter, so that we will know whether the ice is formed by condensation or from water which percolates through the shaft lining.

N. F. HOPKINS: Is there any downcast and upcast there?

P. J. FREEMAN: Yes.

N. F. HOPKINS: Is there any difference in the ice in those?

P. J. FREEMAN: I do not believe there is.

N. F. HOPKINS: Mr. Weber has said that the circular shaft has been advised. I should like to ask Mr. Alford if he has any figures on circular or elliptical shafts.

N. G. ALFORD: There are perhaps seven or eight of these shaft linings that we have listed as failures that are of the elliptical type.

*Chief Engineer, Tests and Specifications, Allegheny County, Pittsburgh.

N. F. HOPKINS: What has been your experience or observation regarding the value of reinforcement?

N. G. ALFORD: That is a point on which we did not make general inquiry. Our information does not enable us to answer that question.

CARL WEBER: Frequently, if old timber shafts are to be relined with concrete, the work is started from the bottom up, and this is quite practicable. Where new shafts have to be sunk, the lining work can proceed only from the top downwards.

E. T. GOTT: We got into so much trouble in sinking the Detroit shaft and were so far behind our schedule that it was decided to go down into the mine and drive upward to meet the shaft gang. This "rise" was driven nine by nine feet, and a distance of about 450 feet was advanced to the break through into the shaft. Working downward, we then enlarged the rise to the full shaft section. The cost of driving and enlarging this rise was about the same as it would have been had we continued the ordinary sinking methods, but we saved about three months in time.

We concreted as we enlarged, coming down in 60-foot runs.

C. H. DORSEY: I once filled a box with concrete and it went down a quarter of an inch in a five-foot section.

P. J. FREEMAN: I think the shrinkage varies with the amount of water and the material.

T. P. WATSON: We have no trouble with the shrinkage of concrete. We have just completed a bridge with 21 piers averaging 20 feet in height. The tops of these piers are finished within two hours of the time the concrete was placed and the settlement, if any, is negligible. I might add that we use a much drier consistency than is usual practice.

R. G. JOHNSON:* The situation as you have presented it has been for several years a source of worry to engineers and contractors who have been engaged in sinking and lining shafts.

*President, R. G. Johnson Co., Pittsburgh.

The disintegration of concrete linings, I am convinced, comes as much from water coming down the shaft, from moisture in the air, from rains, and water from fast-moving cages, as it does from the water from the rock.

I heartily agree that it is vital to drain the rock water properly, and that is very difficult to do, particularly where the flow is small. Invariably it will find its way either through a closing set, around a bunton end, or through the weakest point in the concrete near the point where it leaves the rock.

In circular shafts or in rectangular shafts where the lining is thick enough, it may be possible to grout, and a great deal of water has been shut off in this way, but it is never sure and the chances of breaking the lining through the use of too great a pressure in grouting are always present.

I think you state it wisely when you say that grouting is of little use in a concrete shaft, except in the process of sinking and where it is injected in the rock. I must qualify this to say that closing sets may be so designed as to require, and use effectively, grout under low pressure because there is invariably a shrinkage crack at such a point, and if there is water in the rock near the closing set it will almost invariably flow through the lining at this shrinkage crack. Personally, I believe that the practice of concreting a downcast shaft is doomed unless some means of making an impervious face to the concrete lining is provided. While this has been adjudged practicable by some of the advocates of concrete waterproofing and hardening, I know of no successful method of hardening and waterproofing a face that is wet as a result of water seeping through from the rock. Undoubtedly, denser mixtures and more consistently accurate proportioning of the aggregates in the concrete mixtures will prolong the life of concrete when it is subjected to the extremes that must be present in a shaft lining.

It has been interesting to hear the intimate description of a shaft lining which has failed. I am familiar with this work and have made a number of inspections at different times, at the request of the coal company, to study the situation presented by the gradual failing of the lining. When a cure for the condition was asked for, we gave a plan which they finally adopted. This called for a vitrified-brick lining placed with a concrete backing, all pinned to either solid con-

crete or rock. It required a large amount of chipping of the old concrete and a greater amount of time in drilling the surface for the placing of steel pins to support the brick. All of this would have been of no lasting value if we had not placed vertical drains which connected with branches to all sources of water from the rock. These drain pipes are in the concrete backing behind the brickwork and lead to the bottom of the shaft. The lining has as yet not had a hard winter's test, as the work has been but recently completed, but a report from the general superintendent to-day tells me that the recent freezing spells have apparently shown no ill effects on the lining. Brick was used because we believed it vital to have as impervious a face as is possible so that any water from the moving cages or from downcast air could not penetrate the face and cause it to freeze and disintegrate.

After an experience of twenty odd years at the game with all types of linings, I am firmly convinced that unless we can find some medium to add to concrete that will give the effect of vitrification, some form of brick-faced lining will be used in the best installations of the future.

INDUSTRIAL FUELS*

By H. H. Clark†

You will be surprised when I tell you that gas is the *only* fuel used in industry. Of course I must explain this statement by stating the well-known scientific fact that all fuels must be in the form of gas before combustion will take place.

If you are burning coal on a grate, you are in reality operating a miniature gas-works, because after the burning process has once begun, the heat of combustion of the gases causes the coal to gasify, and the gas thus formed burns to give the necessary heat to your process, and at the same time enough is absorbed by the coal to cause gasification. An ordinary grate might be called the simplest form of gas-producer, and it is likewise the least efficient.

There are some 52 kinds of fuel used in industry. These may be classified as solid, liquid, and gaseous. I have purposely left out electricity as a source of heat for industry, because, thus used, it is so wasteful that its overall efficiency from the coal pile to the finished product on the average is less than five per cent. One pound of coal put through a modern by-product gas plant will deliver four times as much useful heat to the customer's heating process as the same pound of coal put through a modern electric station. Unless some of the advantages claimed for electric heat at this time are based on results that can not be reproduced by other fuels properly applied in well built furnaces, then the electric heating load is not on a permanent basis.

Powdered coal is used for certain special operations, especially cement burning, but for most heating operations there are detrimental effects which limit its successful use.

The solid fuel most generally used in industry is bituminous coal. This is particularly true in Chicago, where I come from, and the middle West. This paper must naturally deal with conditions as I have found them around Chicago, and, strange as it may seem, we were enjoying the advantages of natural gas there some twenty to thirty years ago. It was pumped to Chicago from the gas fields

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†Industrial Gas Engineer, Peoples Gas Light & Coke Co., Chicago.

around Kokomo, Ind., a distance of about 150 miles. Now the natural gas is all gone and we are pumping Chicago gas to Kokomo.

The liquid fuel most generally used is fuel oil. The gas company in Chicago used to consume around 300,000 gallons a day for gas making, but they are rapidly replacing this process with by-product gas ovens. With the great advancement in refining processes, so much of the crude oil is made into higher priced products, such as gasoline, that the fuel oil which is left is getting more and more unsatisfactory for fuel purposes. It is estimated that natural resources of crude oil have a life of only 10 years more, so fuel oil may be considered as somewhat of a temporary fuel, such as natural gas.

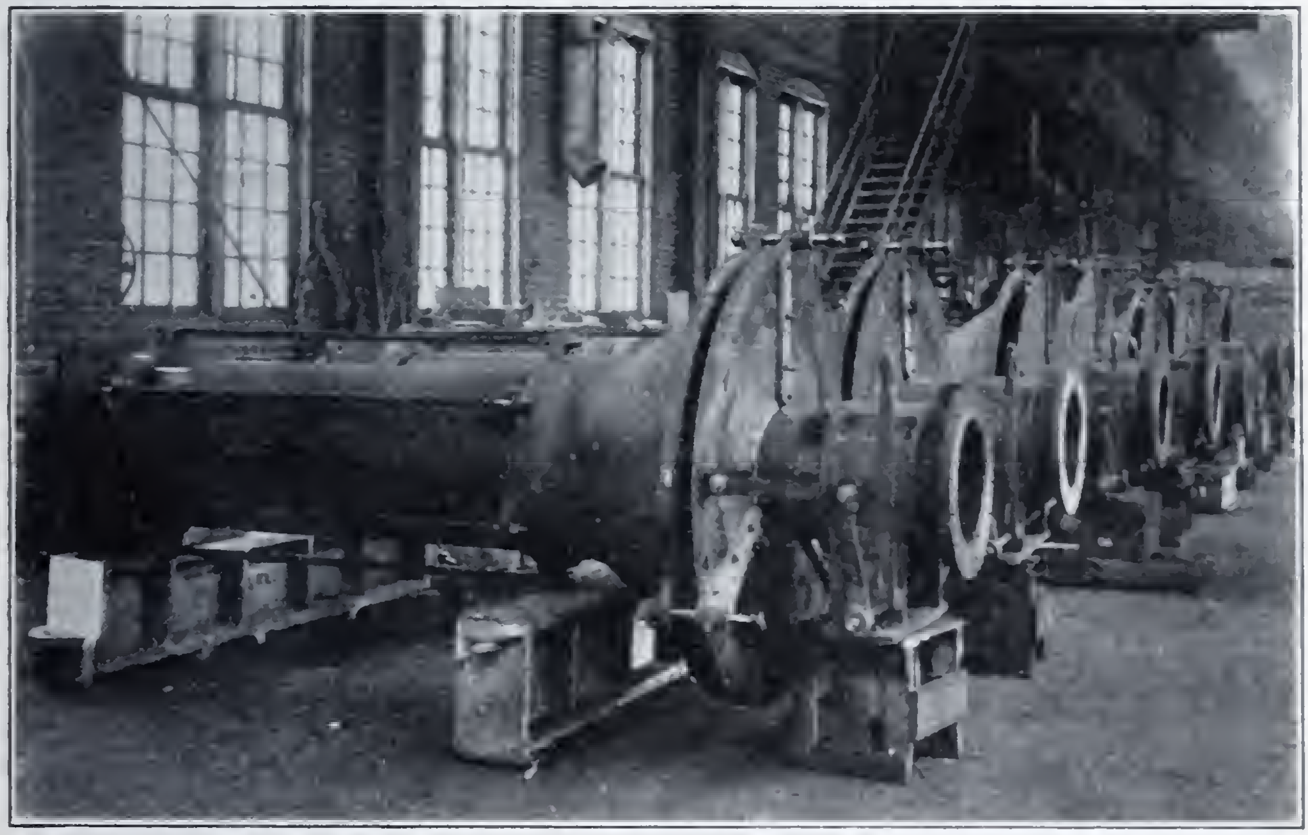

Fig. 1. Burners for Blast-Furnace Gas Being Assembled in Factory.

The principal gaseous fuels are natural gas, city gas, and producer gas. In addition to the above, some work has been done with blast-furnace gas. Fig. 1 shows a group of burners for blast-furnace gas, being assembled in the factory to be shipped to one of the steel-mills. Fig. 2 shows how these burners are applied under boilers. Four burners are used on each boiler. Each burner has a capacity of 400,000 cubic feet of gas per hour. Blast-furnace gas of 90 to 95 B.t.u. per cubic foot is used. We are also experimenting with mixtures of blast-furnace gas and coke-oven gas for heating furnaces.

Producer gas is used extensively in steel-mills and processes where it can be taken hot from the producer and burned raw, taking advantage of the sensible heat in the gases as they come from the producer, as well as the tar, dust, and oils which pass over with the gas. Cold, clean producer gas is not used so extensively.

Natural gas is no longer used around Chicago, because there is none, any more. For a while, the diminishing supply was mixed with city gas, but finally the wells were abandoned and straight city gas substituted in its place. We have had some interesting experience in the past few years, changing our industrial customers over from natural

Fig. 2. Burners for Blast-Furnace Gas under Steam-Boiler.

gas to city gas. The natural gas was of 800 to 900 B.t.u. per cubic foot and sold for 50 to 75 cents per thousand cubic feet, and the city gas is around 530 B.t.u. and sells for the same price. In most instances we found that well-designed furnaces and proper combustion would offset the difference in heating value of the gases. Fig. 3 illustrates furnaces for wire "patenting" using city gas; Fig. 4 shows the fire end of a billet-heating furnace using coke-oven gas; and Fig. 5 shows a plate-heating furnace using city gas. This plate-heating furnace is 12 by 65 feet. It treats plates weighing 1000 pounds, and has a capacity of 90 plates an hour.

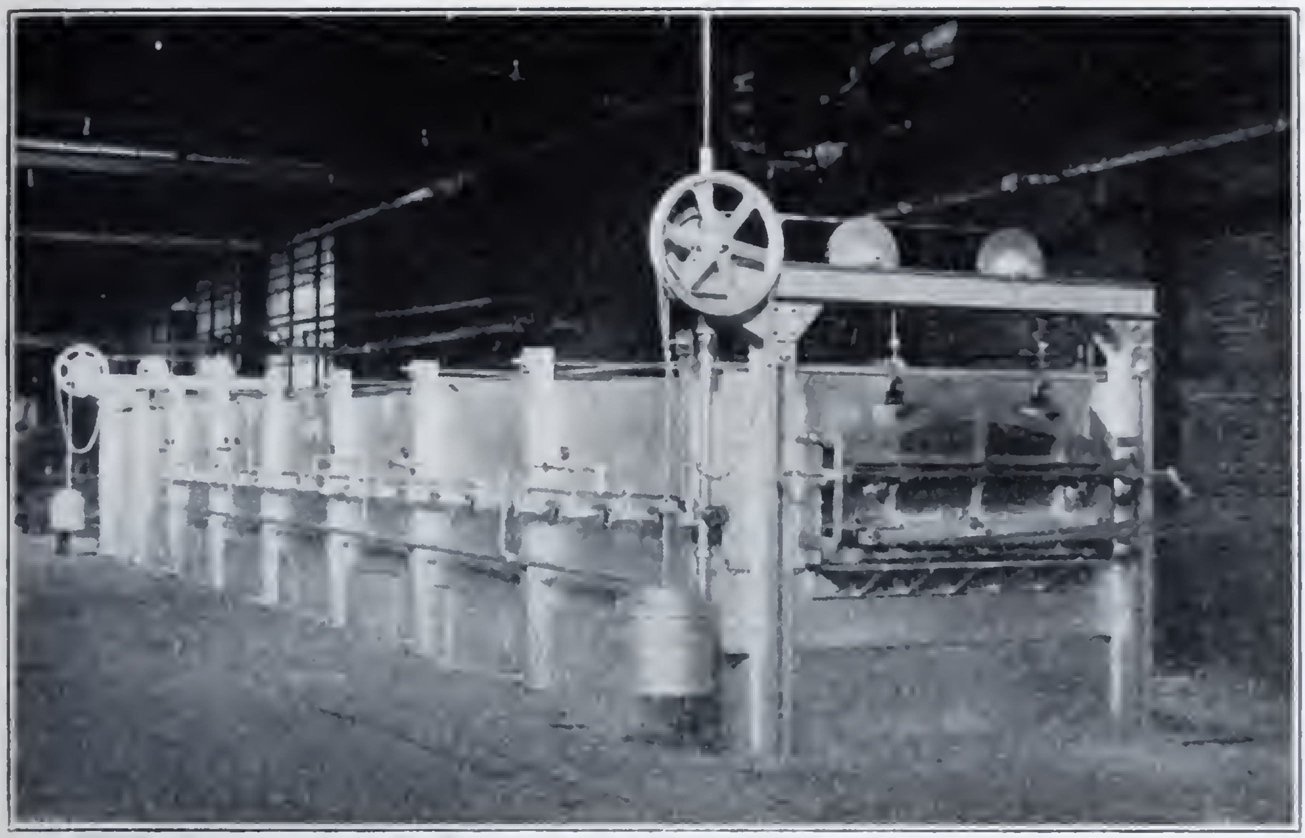

Fig. 3. Furnace for Wire Treatment.

Fig. 4. Billet-Heating Furnace.

City gas is the type with which I am most familiar. It is usually made from bituminous coal in a by-product oven. When gas is thus produced, valuable by-products are recovered, such as coke, which has various uses as fuel, or, as in Chicago, it may be further converted into gas. Other valuable by-products are tar, oils, fertilizers, and drugs. The liquid fuel of the future will come from the by-product gas oven.

From our experience, we have found it best to install new equipment, built for gas. One reason for this is found in the following

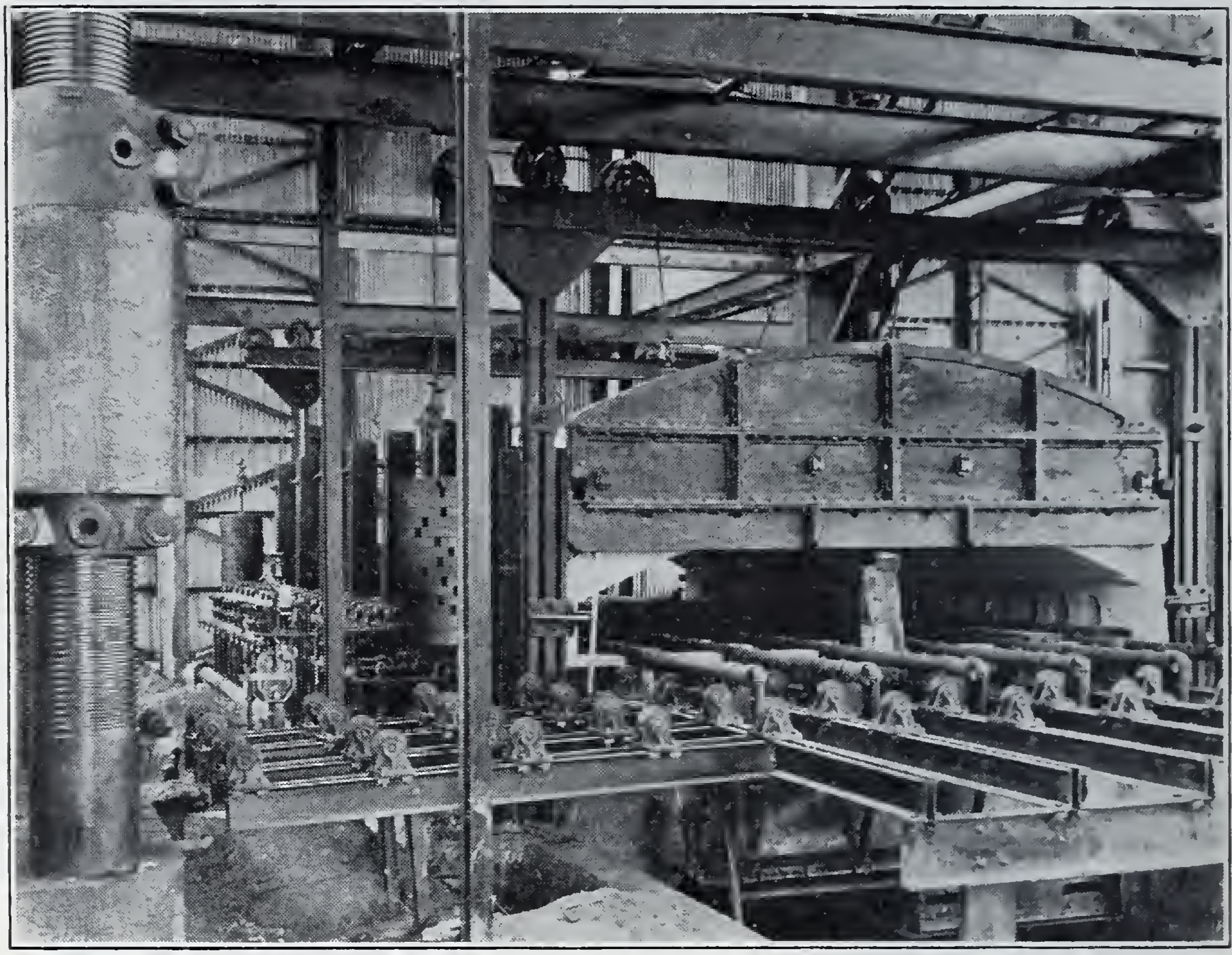

Fig. 5. Plate-Heating Furnace.

figures which from practical results show that, to liberate the same amount of useful heat, the relative volume of the products of combustion of various fuels is about as follows:

City gas, 6; fuel-oil, 8; producer gas, 10; solid fuel, 12.

Obviously, a furnace designed for any one of these fuels can not be used with equal efficiency for any other fuel.

We are firm believers in insulation, and plenty of it, wherever practical. It not only saves fuel, but it improves the room tempera-

ture for the workmen, thereby keeping up production. We also advocate continuous operation of furnaces and processes if practical, especially furnaces of the conveyor and pusher type, when the finishing heat is at one end of the furnace and the material to be heated is charged at the cold end and moved forward by degrees to the finishing end. This not only gives a more uniformly heated product, but it saves fuel by reducing the temperature of the outlet gases.

Just as many of you are specialists in some particular line, we have specialized in the business of gas manufacture and distribution. The subject of gas utilization is also of tremendous importance. We know a lot about how to use gas efficiently, but we always get the advice of the furnace manufacturer before we make an installation. There is just as much specialization in designing and installing efficient gas furnaces as there is in gas making; in fact, more. We can cover up some of our mistakes in the gas plant, but a gas furnace operating in one of your plants must be efficient and as nearly automatic as it is possible to make it. Hence my advice to you is, don't try to build your own furnaces.

Gas-furnace specialists will give you the benefit of their years of experience in building furnaces that are automatic in operation. Some are automatic in temperature control, and others are automatic in control of furnace atmosphere, either neutral, oxidizing, or reducing. In some cases a furnace is completely automatic as to product, temperature, and atmosphere. There are also various means of heat recovery from flue-gases.

The gas industry has a slogan, "If it's done with heat, you can do it better with gas." Whether you buy the gas or make it yourself depends on local conditions.

Among the many things which make American industries superior to those of other nations is specialization; yet thousands of manufacturing companies in this country maintain gas plants as adjuncts to their business. These private gas plants, with their comparatively small production, call for a special department of one or more trained men, demand special purchase of fuel and other supplies, and occupy valuable space in the factory. The gas plant is more or less of a nuisance and a worry, all out of proportion to its importance. Users of coal and fuel-oil for industrial purposes are included in the above for, in reality, they are operating miniature gas plants, because all

fuels must be in the form of gas before combustion can take place, and in these instances the gas is generated in one part of the furnace in a very inefficient manner and burned in another part of the same furnace to do the necessary useful work. Obviously, a furnace can not be a good gas generator and a good heating appliance at the same time.

To-day the private gas plant is in no way a necessity except in special instances. The gas lines of the local gas company pass by the doors of most plants, ready to supply all the gas which the factory

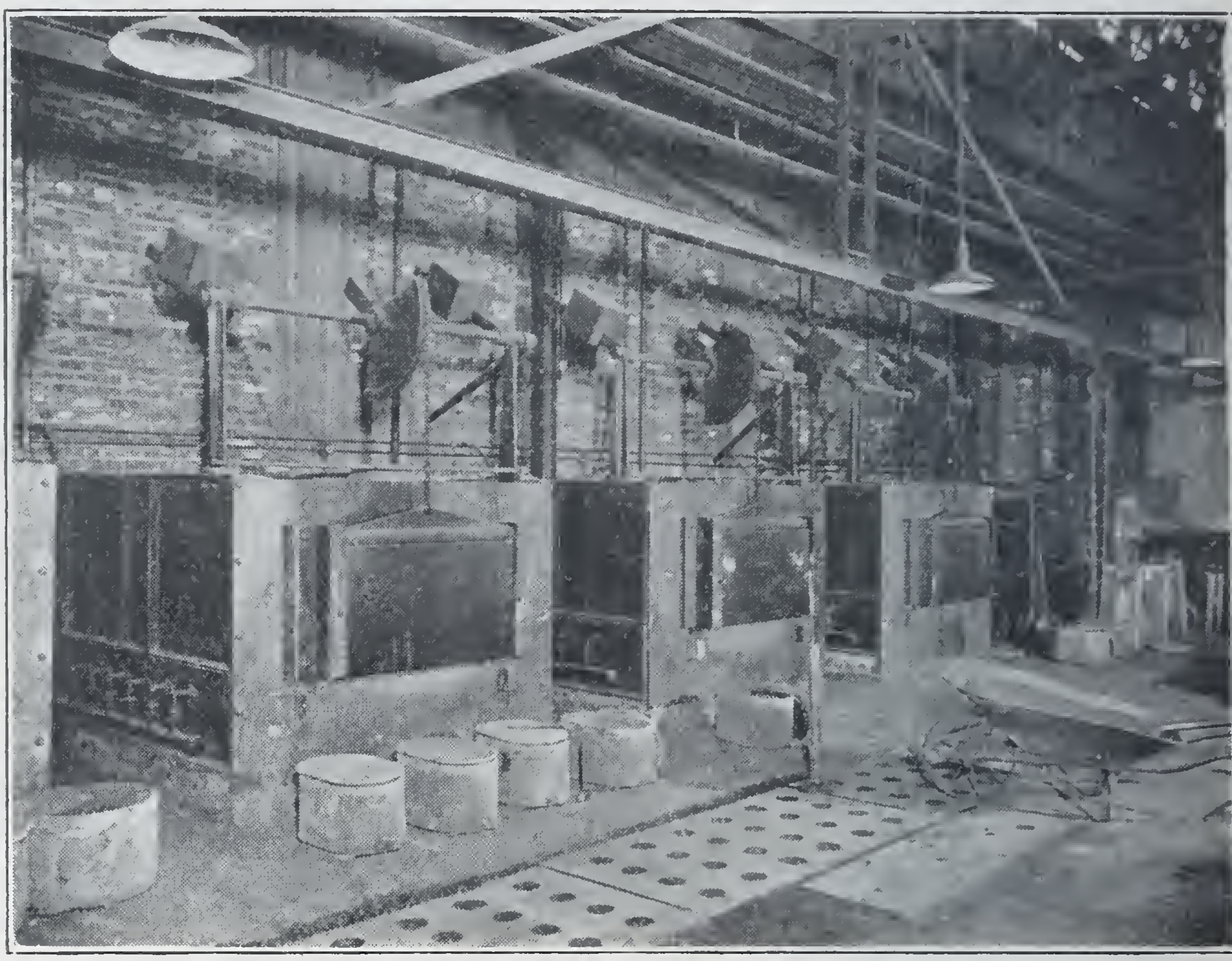

Fig. 6. Carbonizing Furnaces.

needs at a lower cost and in a more reliable manner than is possible from privately operated plants. The wide-awake manufacturing executive will grasp this chance of delegating to the central-station the task of producing the comparatively small amount of gas which his factory may need, thereby entirely avoiding the responsibility for the continual production of gas for his factory. He thereby calls to his aid the services of a specialist, and can devote all of his own time to his own product.

In the middle West we are working out a super gas system that will be the largest in the world, using the gas-generating facilities of Chicago as a center and extending in a circle from Milwaukee, Wis., on the north to Joliet, Ill., on the west; Kokomo and Terre Haute, Ind., on the south; and Gary and Fort Wayne, Ind., on the east. The combined gas-production capacity in this system is nearly 500,000,000 cubic feet a day, exclusive of producer gas or blast-furnace gas.

I am a firm believer in gasification of coal, and the recovery of by-products. I think it is wasteful to burn raw coal. Many wasteful

Fig. 7. Carbonizing Furnaces.

practices are tolerated in this country to-day that will be prohibited in the future; so, whether you make your own gas or buy it, gas is the ultimate fuel, and, as the saying goes, "eventually, why not now?"

What we are doing with gas fuel in Chicago industries is indicated by the following illustrations of typical installations. Fig. 6 shows a group of carbonizing furnaces for pack hardening, and Fig. 7 a group of carbonizing furnaces using gas both for heating and as the carbonizing agent.

I would be pleased to answer any questions, either about the paper or the illustrations. I usually find that a general discussion brings out many points not in the paper, for it is obviously impossible to write a paper in advance that would be of equal interest to every one in the audience.

DISCUSSION

A. E. BLAKE:* There is really little of importance to add to so well written a paper as Mr. Clark's and I believe he has outlined the conditions for the Chicago district very accurately.

In Pittsburgh we have had a different set of conditions, one of which has been very troublesome for the manufacturer and combustion engineer. I refer to the natural-gas shortage and the necessity which has existed for the local gas companies to insist that their industrial customers adopt some other fuel for winter use, or to be used as an auxiliary during the coldest days of winter. Fuel-oil has generally been recommended because its advantages come next to those of gas. The drawback to this can be seen by reference to Mr. Clark's statement with regard to the comparative sizes of combustion spaces required by the various fuels. You will see that he has placed fuel-oil just after gas, but that the oil requires a considerably greater space under theoretical conditions. Under practical conditions this is even greater, for oil.

Manufacturers cannot generally afford two separate sets of furnaces; hence the necessity for furnaces in which either oil or gas can be used as fuel. If designed for gas only, the volume of the furnace can be very considerably less than in the case where the furnace must also be able to do the required work with oil. But the furnaces must operate the year around, and it is not simply a question of additional cost of heat from the use of oil, or greater inconvenience at times when it must be used, but also of the steady loss of heat units at all other times from the increased size of the furnace which makes for additional losses through the greater area of wall, greater first cost due to this difference in size, and other disadvantages. It is due to this condition that the findings of many users of oil and natural gas in combination furnaces do not show natural gas in its true economic position, and we are often told that it is as cheap to use oil as gas, and figures are brought forth to prove it. It is due to this condition that many shops in this district are using oil throughout the year, and the gas companies are attempting by every means to get them to use natural gas during the summer months.

*Pittsburgh Representative, U. G. I. Contracting Co.

The advantages of central gas stations are very well known and they apply particularly to the Chicago district, where much of the industrial gas sale is to relatively small light manufacturing plants, with numerous operations to be performed in finished production, where the requirements are particularly exacting and the value of the product is such that the cost of the heat units required is proportionately very small. In Pittsburgh, for the most part, we have heavy production and the output is usually of a semi-finished character. Higher temperatures generally prevail and the unit cost is lower; hence, while recognizing the value of gas, one of the stipulations is that it shall be at low cost.

These conditions certainly leave room for large industrial concerns to consider privately owned installations for making gas. This is clearly recognized where the operations lend themselves to the use of raw, hot producer gas, which can be made in this district with local fuel at costs ranging from 20 to 30 cents per million B.t.u.'s. Such a cost, including all charges, should, and easily does, preclude the use of natural gas for the heavy melting operations, where slight amounts of dust and some sulphur will not be injurious.

Producer gas, however, especially that from coke, is easily cleaned and can even compete with hot, bituminous, producer gas in heat-unit cost. It is an excellent fuel for industrial uses, and, where the temperature requirements are not high, it is even preferable to the richer gases. It is not suited for lighting, or to be transported for great distances, but its use in industrial plants of any size can generally be well justified in Pittsburgh and vicinity.

The rolling-mill industry seems to be rapidly waking to the use of gas, particularly in the case of sheet-mills. Many sheet-mills have never used anything but natural gas; many others formerly used it and turned to coal for various reasons. These latter are commencing to reconsider the question and are returning to gas wherever it is available.

W. C. Buell:* I always seem to contribute an adverse opinion on the subject of fuels, no matter what the fuel. This comes from my general thought that any fuel is liable to be an unsatisfactory metal-heating medium under specific conditions. Last year the

*Mechanical Engineer, Rust Engineering Co., Pittsburgh.

Youngstown Sheet & Tube Company installed at its Brier Hill plant what was supposed to be the most modern sheet-mill equipment installed up to that time, and the pair-furnaces and sheet furnaces were equipped to burn coke-oven gas with, I think, the same make of gas-burning equipment we have seen on the furnaces shown to-night. The operation of the furnaces has been quite unsatisfactory—so much so that within the last few months they have gone back to coal heating, hand fired, because they could not get the required quality with the gas equipment. In the great majority of cases, gas in some form should be used as fuel. It could, I believe, have been satisfactorily used at Youngstown with the proper furnace design and proper education of heaters.

A. E. Blake: I am glad that Mr. Buell has mentioned this situation at the Brier Hill works. He has told me that he has uttered this warning recently in a New York meeting, where there was no one present able to shed any light on the subject, so that the statement as put could be easily taken as a serious black eye for gas. I have been interested in it because the equipment installed at Brier Hill is of a type in which I have long been interested; so, naturally, I have been at pains to learn just what the difficulty was. As a matter of fact, Mr. E. T. McCleary, of the Youngstown Sheet & Tube Company, who approved the Brier Hill installation, told me last summer that the installation referred to was placed in production as soon as it became available and the demands upon it were heavy. The mill crews were chiefly experienced in the use of coal as fuel, and, being unaccustomed to the equipment, were unable to produce satisfactory results. It became a question, therefore, of slowing down and training them, if possible, and losing production; or of removing the firing equipment, substituting coal, and maintaining the badly needed production. Naturally, the latter course was adopted, with one exception. On one mill the crew had become able to make the required production in full-finished sheets with the use of by-product gas, and they have continued the use of gas without interruption, proving that there is no reason whatever to condemn the firing equipment or the gas. I was told that when the opportunity afforded, the question of replacement of the original firing equipment would certainly become very much alive.

It is well to note that this experience is not deterring other people from making installations of gas-firing equipment in sheet-mill furnaces. To all of us here it seems very absurd, I am sure, to think that gas is unfitted for this particular service when we can point to so great a number of mills that have never used anything else. Those interested in the subject will find that an article in *Fuels and Furnaces*, by A. W. Peters, describing the lay-out, and stating the performance of the furnaces of the West Penn Steel Company, will bear me out. This article occurs in volume 2, March, 1924, on pages 227-230. It would be hard to find a mill with a better reputation for the quality of its product than the one referred to.

As a matter of further interest, and serving to show that the kind of gas has little influence, so long as it will provide the necessary heat units, and is clean enough to permit handling in refined equipment, I can say that the Youngstown Sheet & Tube Company has applied blast-furnace gas, with complete success, to the heating of sheet-mill furnaces.

E. J. Stephany:* I should like to take issue with Mr. Blake. I realize that his information about gas service in Pittsburgh has grown very rusty since he has left the business of selling gas-burning equipment and has gone into the business of selling gas-producing equipment. For his information I can state the fact that no industrial user of gas in Pittsburgh has been shut off during the last four winters. We have never refused to supply gas when it was wanted.

But, going back to the paper, I have known Horace Clark for nearly 13 years and during all that time I have considered him to be one of the foremost fuel engineers in the country. I am sorry that he is not here to tell us more of what he knows than is contained in this short paper read in his absence.

Mr. Clark has coined a phrase, "It is not the cost of *buying* a fuel but the cost of *using* it that counts." There is a lot of truth in this statement. I have seen some of Mr. Clark's analyses and, of course, he does not compare fuels on the basis of the cost per B.t.u. alone. His analysis goes all the way through the various costs and gets down to the cost per unit of production. This is what really counts, and it is one of the reasons why the use of a higher-priced fuel, manufactured gas, has been so successful in Chicago.

*Superintendent of Sales Department, Equitable Gas Company, Pittsburgh.

I am very much interested in Mr. Clark's reference to the fact that the cost of using their gas of lower B.t.u. is not any higher than the former cost of using natural gas. We have found this to be true also in Pittsburgh, particularly in the domestic use of gas for cooking, water heating, etc. The total cost of using gas now is not any higher than it was formerly, in spite of higher rates for gas. Gas was formerly used so wastefully that the application of more economical methods has overcome the increased unit cost of gas. Mr. Clark's intimation that further economies are possible is very important to us here in Pittsburgh.

A. E. Blake: I heard recently that the Ford Motor Company has substituted clean producer gas for Detroit city gas, and when this was done they also made improvements to some of the furnaces and selected more efficient burners; so that in one or two instances they actually found themselves using a smaller *volume* of producer gas than they formerly used of the city gas. The city gas probably ran somewhere near 540 B.t.u's and the producer gas in the neighborhood of 160 B.t.u.'s.

Another fallacy, which is being pointed to with as much emphasis as possible by fuel engineers, is that those who drifted away from the use of gas fuel for various reasons, have argued that other fuels were cheaper, without realizing that they had failed to give the gas a square deal; in other words, they discarded, along with the gas, very inefficient burning equipment and furnaces, and installed in their place carefully designed equipment to use other fuel. When one has had an opportunity to see in actual operation some types of the furnaces that were abandoned, there is little to be wondered at when they make the statement that some other fuel has proved cheaper. In many instances the gas companies in this district have persuaded the manufacturers to install the proper kind of gas equipment, with the result that the owners have been very glad to be using gas once more. The type of equipment which has been illustrated in Mr. Clark's paper has been responsible for many such instances.

E. B. Plapp:* Several summers ago while working at the Indiana Harbor plant of the Inland Steel Company, I noticed the

*Mechanical Engineer, U. S. Aluminum Co., New Kensington, Pa.

difference between that section of the country and this section, as to conditions. Over the Sunday period we used to sell quite a bit of by-product gas to the Peoples Gas Light & Coke Company. The Inland Steel Company plant was ten or fifteen miles from Chicago and around that whole section were quite a few mills. That gas company was buying all the by-product gas it could get, and storing it. Of course, that meant a great amount of storage to take care of the gas, but they bought gas when we had enough pressure to get it to them.

At this same Inland plant, powdered fuel was used in heating some of the slabs used to make plates. I do not remember much of the installation except that I know that they could heat those slabs pretty rapidly.

I also want to take issue with a statement made by the author of the paper. He said that electricity in the use of heating is the least efficient, and he practically threw it out. That is all right where it is produced from coal. But there are places where electricity is produced by water-power, which makes considerable difference. I think that especially in the paper-mills and other mills of Canada, where there is a great deal of water-power and fuel costs a great deal, electricity has a real use for heating.

I would like to bring up one question, because it is one in which I have been interested lately—the question of devices for protecting furnaces from explosion. Is there any device known which, in case the gas is shut off—either turned off or blown out by a draft—will prevent the formation of an explosive mixture that will cause damage when gas accumulates in the furnaces? Can any one give me information that would lead to such a device, if there is such a one on the market?

W. M. Austin:* I think the contention that the fuel is burned as gas even when put into the furnace as coal or coke is only partially so, because the fixed carbon, in order to be converted into gas, must be burned to CO and thereby must liberate some of its energy. It is, of course, immaterial how the fuel is burned if it is burned efficiently. It was estimated a few years ago that there were about nine dollars' worth of volatile products obtainable, in addition to the

*Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

coke, from every ton of good bituminous coal at the then market price for these products. It may be that the non-condensable gases have been valued at a higher price than they should have if they are to compete with coal or coke under a boiler or in connection with metallurgical processes.

I think there is no doubt whatever that fuel users will change from coal or coke to gas just as soon as they can buy the same amount of extractable heat in the form of gas fuel for what they now pay for it in the form of coal.

I suppose the automatic mixing devices on the gas-burners have to be designed or proportioned for the particular fuel used. Coke-oven gas changes quite materially at the end of the heat from what it is at or near the beginning. Where the number of ovens is small, has there ever been any trouble in maintaining the desired atmosphere in a furnace due to change in the relative proportion of carbon and hydrogen in the gas?

Charles A. Blesch:* I might answer some of these questions. The gas composition possibly does change within narrow margins, particularly coke-oven or producer gas, but within practical commercial ranges this equipment is entirely practicable and the slight change in gas composition is virtually unnoticeable. In order to change from coke-oven gas of 530 B.t.u. per cubic foot to natural gas of 1000 B.t.u. per cubic foot, it is merely necessary to change the diameter of the gas orifice. This would change the capacity of the burner somewhat, but it would maintain the proper proportions with the richer gas without a complete redesigning of the burner. I know of one large plant where natural gas is fired in the summer time through this type of equipment and clean producer gas is fired in the winter time through the same burners by merely changing the gas orifice; thus you will see that it is readily possible to design the equipment capacity to give the proper heating with either of several gaseous fuels available.

A. E. Blake: As to the question of substituting one gas for another, I would point out that it so happens that a cubic foot of combustible air-gas mixture in proper proportion for quantitative or perfect

*Sales Engineer, Surface Combustion Co., Pittsburgh.

combustion in the case of the various high-duty gases—such as natural gas, coke-oven gas, and the types of gas generally supplied in large cities—has from about 90 to 100 B.t.u., so that the substitution of one gas for another means only the substitution of a mixture different from another at the burner nozzle, and these can be so chosen for size that it would be unnecessary to redesign them for a change in the fuel. In fact, there is an instance in this district (at New Brighton, Pa.) where 16 enameling furnaces are operated alternatively, either on producer gas, of about 160 B.t.u., or natural gas, the former coming to the inspirators at about a pound pressure, and the natural gas, when required, supplied through a compressor at 20 pounds. It is the small gas spud by which the gas stream under pressure is projected into the air-inspirating throat that requires to be changed, and this is accomplished by a very simple movable device carrying the spuds of the two required sizes, so that it is only a question of a few minutes to change from one gas to the other on all 16 furnaces, a matter of about 30 minutes, and there are 96 burners in all.

I have always found that specific information on the properties of various kinds of gas is gladly received, so I venture to present Table I, which I have prepared to compare directly with one another the principal properties of six different industrial gases. The data used in the calculations have been taken from a booklet entitled "Combustion," compiled by the Committee on Industrial Gas, of the American Gas Association. The booklet can be secured by addressing the American Gas Association, 342 Madison Avenue, New York.

Answering the other gentleman who wished to know how blow-off at the nozzle is prevented, I would say that the type of burner referred to is so installed that its nozzle delivers the air-gas mixture at the base of a suitable recess or tunnel in the furnace wall, lined with refractory cement. This tunnel is so designed that some of the expanding mixture, in sweeping over the tunnel surface, is retarded enough so that, once ignited, it will remain in combustion and thus communicate the combustion to the main body of mixture being projected into the furnace space. This initial combustion on the tunnel surface serves to heat it and, as the temperature increases, the amount of combustion in that vicinity increases. This becomes especially marked when the surface gets to a red heat, when the well known catalytic action of light energy exerts its influence strongly

TABLE I. VARIOUS GASES COMPARED

CONSTITUENTS	West Virginia natural gas	Blue water-gas	Bituminous producer gas	Coke producer gas	By-product oven gas	Mixed gas 300 B.t.u.*
	PER CENT.					
CO	.....	43.5	25.3	30.96	7.0	20.55
H_2	.....	47.3	9.2	9.3	55.4	29.38
CH_4	84.0	0.7	3.1	0.7	26.1	11.76
C_2H_6	15.8	.....	.....	.....	2.5	1.09
CO_2	0.2	3.5	3.4	3.56	2.0	2.88
N_2	.....	4.4	58.2	55.43	7.0	34.40
O_2	.....	0.6	.....	0.05	.....	0.03
C_2H_4	.....	.....	0.8	.....	.....	.....
TOTAL	100.0	100.0	100.0	100.00	100.0	100.09
COMMON PHYSICAL PROPERTIES						
B.t.u. (gross)	1125.3	302.0	155.9	137.6	511.2	300
B.t.u. (net)	1011.1	276.3	146.8	131.8	449.5	269.9
Theoretical flame temperature	3673° F.	4180° F.	3170° F.	3190° F.	3790° F.	3610° F.
Ratio of gas volumes to air volume for theoretical combustible mixture	10.684	2.211	1.239	1.027	4.397	2.501
B.t.u. per cubic foot of theoretical air-gas mixture	96.37	94.06	69.6	67.86	94.5	85.6
Volume of combustion products per volume gas burned (gross)	11.961	2.762	2.066	1.826	5.103	3.259
B.t.u. concentration per cubic foot of combustion products, assuming reduction to be 30-60 (gross)	94.14	109.34	75.3	75.34	99.98	92.0
Concentration of water vapor in combustion products	18.01	17.6	8.2	5.86	22.50	17.24

*Coke producer gas, 43.5 per cent. By-product oven gas, 55.5 per cent.

upon the thoroughly mixed air and gas molecules. Eventually, and that means a very few minutes in actual practice, the tunnel surface is intensely incandescent and the radiated energy completely surrounding the issuing combustible mixture has the effect of completing the chemical reaction by the time the gases have issued from the tunnel itself. You can see, therefore, that a temporary stoppage or variation in the flow of mixture will cause no harm, because the incandescent tunnel will serve as a torch for a considerable period after the interruption of flow, and relight the mixture.

Natural gas is generally regarded as quite sluggish in its action, but one can look directly into such a burner tunnel in operation, say from the opposite side of a pair-heating furnace, and the only visible evidence of combustion will be the incandescent tunnel walls and furnace interior, and a very faint wavering, blue haze just in front of the tunnel itself. Through this the cool, black burner orifice is easily visible.

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Wm. Penn Hotel, Wednesday, Feb. 17th at 4:50 P. M. Vice President John A. Hunter presiding, Messrs. Weldin, Clifford, Affelder, Edgar, Spellmire, Hopkins, Shaw, Covell, Rice and the Secretary being present.

The Minutes of the last meeting held Jan. 19th, were approved without reading.

Applications for membership from the following gentlemen having been published to the Society, pursuant to the action of the Board, were elected to membership.

MEMBERS

Dyrssen, Waldemar	Maddox, John DaCosta
Graf, Julius Eicher	Nicholls, John A.
McFarlen, Joseph Pettis	Steidle, Edward

ASSOCIATES

Benedict, John Blakesley	Davis, Paul G.

JUNIORS

Cutler, Day Emerson	Macy, Theodore E.
Harmon, Forrest Graves	Terman, Mark J.

Applications for membership were received from the following gentlemen and their names ordered published to the Society.

MEMBERS

Adams, Frank Lester	Hoffman, William Guy
Albrecht, Frederick C.	Kinter, Charles Willis
Bloomquist, O. A.	McCrystle, J.
Brotzman, William S.	McIlvried, Howard George
Cate, Edgar A.	Nimick, Alexander
Dauler, Cyrus Sylvester	Shafer, William B.
Davis, Ralph Emerson	Sipe, Charles Allen
Etheridge, Harry	Swanberg, Floyd Ludwig
Fowler, William E.	Taggart, Ralph S.

Wallace, William W.

ASSOCIATE MEMBERS

Burgess, Edgar Allan	Mayhew, Norman H.
Ewald, Harry W.	Reed, Norman James
Johnson, Edwin H.	Trimble, John L.

ASSOCIATE

Gamble, Earl Rolland

JUNIORS

Gordon, Bennett Taylor	Lahr, Robert W.

Applications for transfer to higher grade of membership were received from the following members and after discussion, the Secretary was requested to advise them of their transfer to the following grades:

Hopwood, J. M. (Member) Stripe, W. C. (Member)
Wilcoxson, Leslie Swales (Associate Member)

The report of the Secretary, showing the financial condition of the Society at the close of business Jan. 31st, having been audited by the Finance Committee, was approved.

In the absence of Mr. Fohl, the Secretary reported the appointment of the following chairmen.

Entertainment	T. C. Clifford
Finance	John A. Hunter
House	W. A. Weldin
Membership	W. L. Affelder
Publication	G. M. Goodspeed

Mr. Clifford, Chairman of the Entertainment Committee, reported that he had reappointed the same committee which served last year and they had all agreed to serve.

Mr. Hunter, Chairman of the Finance Committee, stated that the following men had been appointed and had agreed to serve on the Finance Committee for the coming year. Taylor Allderdice, N. F. Brown and Graham Bright.

Mr. Hunter stated that the Committee had prepared a budget of expenditures and receipts, which he asked the Secretary to read. He also stated that he had not been able to get his committee together before the Board meeting and had asked the Secretary to take the budget around to the various members, who had approved it. The Budget has been made up on a conservative basis, taking into consideration the 1925 estimated and spent.

ESTIMATED EXPENDITURES

Rent	$6,000.00
Salaries	8,520.00
Year Book	600.00
Miscellaneous Printing	1,600.00
Postage	1,100.00
Office and Miscellaneous	1,200.00
Entertainment Committee	1,500.00
Reporting	450.00
Auditing	225.00
Society Pins	150.00
Total	$21,345.00

ESTIMATED RECEIPTS

MEMBERSHIP

Members:		
Resident	1009	$15,135.00
Non-Resident	225	2,250.00
Associate Members:		
Resident	143	2,145.00
Non-Resident	11	110.00
Associates:		
Resident	63	787.50
Non-Resident	7	52.50
Juniors:		
Resident	90	900.00
Non-Resident	15	112.50
Student Juniors:		
Resident	5	15.00
Total	1568	$21,507.50
Sale of PROCEEDINGS		700.00
Interest		1,000.00
Society Pins		150.00
Totals		$23,357.50

The Committee also considered three items which they wished to recommend to the Board to be included in the budget submitted. First, a picture screen for use at our meetings and other functions, as the sheet furnished by the hotel is not satisfactory and sometimes we do not get the best results from the slides of our speakers.

Second, a bulletin board to replace the blackboard in the rooms of the Society. This recommendation is made on the endorsement of the House Committee who went into the matter and believed such a board would be a good addition to our equipment. Most of the members making use of our rooms look to this board for announcements of activities and it is felt that in purchasing a board with removable letters, we could announce our meetings more in detail than we can with our present board. The cost of this board is estimated at $102.00.

Third, the Committee wished to recommend an increase in salary for H. McNicol, of $15.00 per month.

After a general discussion, the budget as a whole and the three additional items were approved.

Mr. W. A. Weldin, Chairman of the House Committee, reported that he had appointed Messrs. R. P. Forsberg, H. A. Ingram and C. M. Reppert as members of his committee for the coming year and they had agreed to serve. The Committee held one meeting at which the matter of securing a screen and bulletin board was discussed and approved. The Committee also reported an evening attendance of 456 for the month of January.

Mr. Affelder, Chairman of the Membership Committee, reported that one meeting of the Committee had been held to make assignment of applications received since the last meeting of the Board.

Mr. Goodspeed, Chairman of the Publication Committee, reported that the following men have been appointed to serve on his committee and had all agreed to serve. Messrs. Norman Allderdice, J. B. Crane, Julian Kennedy, Jr., E. R. Weidlein, Sydney Dillon, Andrew Pinkerton, James Milliken, W. M. McKee, also the section Chairman. The program for the balance of this year is in good shape and the committee expects to meet in the near future to arrange the program for the season 1926-27.

The Secretary retired from the room while the election of the Secretary took place and K. F. Treschow was elected Secretary at a salary of $5000 per year.

Mr. Spellmire called the attention of the Board to a meeting of the Pennsylvania Street Railway Association to be held in Pittsburgh in March and suggested that we extend the courtesy of our rooms to their members during their stay in Pittsburgh. It was regularly moved and carried that Mr. Spellmire be authorized to extend this invitation.

Mr. Weldin called the attention of the Board to the meeting of the A. I. M. & M. E. next October with the suggestion that we offer the courtesy of our rooms and assist them in any way possible to make their meeting a success. It was suggested that Mr. Fohl was active in this organization and that at the proper time he could probably advise us as to just how we could be of service to them.

Mr. Covell brought up the matter of presentation of a paper on our Liberty Tubes. He stated that the Civil Section had for several years tried to secure Mr. Neeld's consent to present the paper on the Tubes, but that Mr. Neeld had been in bad health and had been out of the city almost continuously. He stated that his office had received so many requests, that finally one of his men had collected all data available and had written a paper, which he would be glad to offer the Society.

It was moved and carried that this matter be taken up with Mr. Goodspeed, Chairman of the Publication Committee with the recommendation that this meeting be scheduled as soon as possible.

The Secretary presented a letter from Mr. Knowles asking for the opinion of the Board of Direction as to whether it wished to go so far as to agree with and promote activities which would mean the shelving of the Engineer Corps of the U. S. Army in connection with the formation of a National Department of Public Works. Mr. Knowles felt that this might be unwise and that all of the benefits of coordination in a Department of Public Works may be secured without such action.

It was moved and carried that Mr. Knowles be invited to the next meeting of the Board in order that they might have the advantage of his advice before taking definite action.

Mr. Spellmire brought up the matter of the dues in the Society of the Secretary and it was moved and carried that his dues for the year 1926 be remitted.

The meeting adjourned at 5:50 P. M.

K. F. Treschow, *Secretary*

ANNUAL MEETING—MECHANICAL SECTION

The Annual meeting of the Mechanical Section of the Engineers' Society of Western Pennsylvania was held in the Wm. Penn Hotel, Room 50, Parlor Floor, Tuesday Evening, February 2nd at 8:15 P. M. Mr. R. E. Polk presiding in the absence of the Chairman, 55 members and visitors being present.

The Minutes of the last Annual Meeting were read and approved.

The Annual report of the Section was read by the Secretary.

The report of the Nominating Committee was read by the Secretary, as follows:

February 2, 1926.

To Members and Officers, Mechanical Section.

Dear Sirs:

Your Nominating Committee met to-day at 12 o'clock to nominate officers for the Section for the ensuing year, and have nominated the following:

Chairman .... Wm. Shaw
Vice Chairman .... R. E. Polk
Directors .... C. A. Carpenter, W. P. Chandler, G. E. Dignan, J. S. Fulton, J. I. Thompson

Respectfully submitted,

Sydney Dillon, *Chairman,*
H. A. Ingram,
R. M. Rush,
Nominating Committee.

On motion the nominations were closed and the Secretary instructed to cast a unanimous ballot in favor of the officers named and they were, thereupon, declared elected.

There being no further business, the paper of the evening was presented by Mr. H. C. Adams, of the Equitable Gas Co., in the absence of the author, Mr. H. H. Clark, Industrial Gas Engineer, Peoples Gas, Light & Coke Co., Chicago, Ill., on Fuels in Industry.

The ensuing discussion was participated in by: W. M. Austin, Engr., Westinghouse Elec. & Mfg. Co.; W. C. Buell, Jr., Engr., Rust Engineering Co.; E. J. Stephany, Supt., Sales Department, Equitable Gas Co.; A. E. Blake, Pgh. Repr., U. G. I. Contracting Co.; Charles A. Blesch, Sales Engr., Surface Combustion Co.; E. B. Plapp, Mech. Engr., United States Aluminum Co.; and Mr. Adams, for the author.

On motion duly seconded and carried, a vote of thanks was extended to the author of the paper and to Mr. Adams for reading it.

The meeting adjourned at 9:30 P. M.

K. F. TRESCHOW, *Secretary*

REGULAR MONTHLY MEETING

The 436th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Blue Room, Wm. Penn Hotel, Tuesday, Feb. 16th at 8:15 P. M., Past President Harry J. Lewis presiding in the absence of the president, 50 members and visitors being present.

The Minutes of the last meeting held Dec. 15th, were read and approved.

The Board of Direction reported the election of six applicants to the grade of Member, two to the grade of Associate and four to the grade of Junior and the receipt of 23 applications for membership. Three members were transferred to the grade of member and four resignations were accepted.

Mr. John A. Hunter, Vice President, then assumed the chair.

No further business coming before the Society, the paper of the evening on European Industrial Conditions and Their Interest to the American Engineer was presented by Dr. Walter F. Rittman, National President, Society of Industrial Engineers and Head, Department of Commercial Engineering, Carnegie Institute of Technology, Pittsburgh, Pa.

The ensuing discussion was participated in by: Victor V. Grey, Engr., The Koppers Company; Harry J. Lewis, Consulting Engineer, Pittsburgh; J. M. Totten, Asst. Test Engr., Carnegie Steel Co., Duquesne, Pa.; Winters Haydock, Chief Engineer, Transit Commission, City of Pittsburgh and the author.

On motion duly seconded and carried, a vote of thanks was extended to Dr. Rittman for his very interesting talk.

The meeting adjourned at 9:41 P. M.

K. F. TRESCHOW, *Secretary*

STEEL WORKS SECTION—ANNUAL MEETING

The Annual meeting of the Steel Works Section of the Engineers' Society of Western Pennsylvania was held in the Blue Room, William Penn Hotel, Tuesday, Feb. 23rd at 8:20 P. M. 70 members and visitors being present.

The Minutes of the last Annual meeting held Jan. 27th, were read and approved.

The Annual report of the Section was read by the Chairman.

The report of the Nominating Committee was read by Mr. R. E. Butler, Chairman, as follows:

To Officers and Members, Steel Works Section.

DEAR SIRS:

Your Nominating Committee met to-day to nominate officers for the Steel Works Section for the ensuing year and wish to present the following:

Chairman	A. C. Fieldner
Vice Chairman	T. J. McLaughlin
Directors	D. D. Pendleton B. R. Shover S. S. Wales C. F. Freeman W. B. Skinkle

Respectfully submitted,

R. E. BUTLER, *Chairman,*
J. D. HILES,
Nominating Committee.

On motion duly seconded and carried, the nominations were closed and the Secretary was instructed to cast a unanimous ballot for the officers named, who were, thereupon, declared elected.

No further business coming before the Section, the meeting was adjourned and the regular bi-monthly meeting called to order by the new Chairman, Mr. Fieldner.

The address of the retiring Chairman was presented by Mr. L. C. Edgar, Chief Engineer, Edgar Thomson Works, Carnegie Steel Co., Braddock, Pa., on Steel Plant Operating Costs from an Engineering Point of View.

The ensuing discussion was participated in by: Dr. John S. Unger, Mgr., Research Bureau, Carnegie Steel Co.; A. E. Blake, Pgh. Repr., U. G. I. Contracting Co.; H. B. Mann, Engr., Dravo-Doyle Co.; E. B. Plapp, Mech. Engr., U. S. Aluminum Co., New Kensington, Pa.; A. C. Fieldner, Supt., Pittsburgh Experiment Station, U. S. Bureau of Mines; and the author.

On motion duly seconded and carried, a vote of thanks was extended to Mr. Edgar for his very excellent paper.

No further business coming before the Section, the meeting adjourned at 9:47 P. M.

K. F. TRESCHOW, *Secretary*

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PROFESSIONAL CARDS

VOL. 42 APRIL 1926 No. 3

PROCEEDINGS
OF THE
ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA

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All papers, upon their acceptance by the Publication Committee, become the property of the Society, and it lies within the discretion of the Committee to publish them in whole or in part. The Society, however, does not hold itself responsible for opinions expressed by its members.

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Incorporated 1880

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THE GEODETIC AND TOPOGRAPHIC SURVEY OF PITTSBURGH AND ALLEGHENY COUNTY*

By U. N. Arthur† and R. H. Randall‡

INTRODUCTION

The realization of the need of a comprehensive and accurate city survey of Pittsburgh dates from the earliest organized interest in city planning matters of the district. In a report, "Pittsburgh Main Thoroughfares and the Down Town District," 1911, prepared for the Committee on City Planning of the Pittsburgh Civic Commission§ by Mr. Frederick Law Olmsted, the value of such a survey is stressed. While the general purpose of this paper is the detailed description of the survey and the progress attained thus far in each of the various elements which compose it, it may be well to give here a few facts regarding its general character and purpose.

The city survey, here officially termed the Triangulation and Topographic Survey from its two principal divisions, is an inventory of the physical facts relating to the surface of the ground and to the public improvements thereon. It seems trite and too obvious to say that, since land is the only thing a city has to build itself upon, the city should early possess itself of these facts; and yet it is true that Pittsburgh, in common with most American cities, has only recently begun the comprehensive and systematic assembling of this information. Hitherto such knowledge of this character as was possessed was obtained piecemeal by small surveys for specific and unrelated problems, was speedily lost sight of, and so was valueless beyond its immediate purpose. Perhaps the most salient point of the present survey is its fundamental and lasting character. It is designed to obtain every bit of the necessary information throughout its area, and, because of its high accuracy, to do this without appreciable error. It is further so designed as to permit of indefinite expansion upon the same basis, as the future needs of the district may require.

Briefly described, the topographic survey is a bird's-eye view of

*Presented December 15, 1925. Received for publication March 23, 1926.
†Chief Engineer, Department of City Planning, City of Pittsburgh, Pittsburgh.
‡Engineer of Survey, Department of City Planning, City of Pittsburgh, Pittsburgh.
§Pittsburgh Civic Commission. Publication 8.

the city or of a part of its area. Reduced in scale to desk size, it portrays, by means of contour lines and other symbols, the hills and hollows, streets and watercourses of the section under consideration. From it the exact elevation and shape of the ground's surface at any point may be readily ascertained, and by its use the best and most economical locations and routes for streets, viaducts, bridges, sewer and water lines, parks and all public improvements may be determined. A further and very definite use is in the determining of proportional assessments for improvements, especially sewerage and drainage projects, on the benefit-assessment system. Specific instances of its use may be multiplied without number, for they are almost as broad and varied as the city's activities. Broadly speaking, the survey supplies a sure foundation of facts upon which scientific planning and replanning may be conducted.

The triangulation, precise traverse and precise levels later described are all necessary, integral parts of the survey and an invaluable basis for all of the city's engineering activities. The accurate co-ordinates, bearings and distances determined for the monuments and reference points of these divisions of the survey will be transferred to and incorporated with existing property and street monuments, thus making possible the exact replacement of such property and street markers when lost through regrading or other causes.

Appreciating the fact that the need of basic planning data is not limited to the incorporated area of Pittsburgh, Allegheny County, through its Department of Public Works and the County Planning Commission, has been co-operating with this department since July 1, 1925, in extending the present survey. Triangulation, precise traversing and leveling have been started in the county. The city and county surveys are fully co-ordinated.

It is planned that the Pittsburgh survey shall be fundamental and comprehensive in character. To make this possible, consideration has been given to the ideal schedule of the community's necessary basic engineering information, and to the preparation of definite specifications covering each division. The detailed specifications and their characteristics will be indicated hereinafter. The general schedule adopted is as follows:

1. Precise triangulation over the metropolitan area. The stations of this triangulation should average about one per square mile in

incorporated or built-up territories, and about one for every two square miles throughout the rest of the county; the accuracy of the triangulation to be such that the probable error of any distance will not exceed one part in 100,000.

2. Precise traverse amplifying and making usable the results of the triangulation. The stations of the traverse should be well monumented and referenced, and should coincide as far as practicable with existing property monuments. The traverse should have an accuracy represented by a limiting closing error of 1 : 20,000.

3. Precise levels with elevations established upon bench-marks on permanent structures along the routes and upon traverse and triangulation monuments.

4. Topographic map published upon a scale of one inch equals 200 feet.

5. Property map upon a scale of one inch equals 50 feet. This is the base map for all departmental information where figures and dimensions are required. Editions of this map may also be used for underground structures, etc.

6. Wall or desk map on a scale of one inch equals 800 to 1000 feet, showing streets and, in general, the same data as given upon the larger-scale topographic maps from which it is to be compiled.

TRIANGULATION

Description. Triangulation is the framework or foundation of the horizontal survey. It is basically a series of overlapping triangles. Angles of these triangles are measured, and at proper intervals a triangle side is also measured. From this side length, measured upon the ground, lengths for the air-lines which constitute all other triangle sides are computed by trigonometric rules. On account of the overlapping of the triangles certain geometrical figures are formed, which, with the triangles themselves, are subject to rigid geometrical laws, making this form of survey capable of great accuracy in adjustment and computation and in the consequent quality of final results. Triangulation may be considered as being, generally speaking, of either a linear (or chain) type—usually executed for cross-country control—or of the area type, such as is essential for cities and counties. The present survey is, of course, of the latter sort (See Fig. 1).

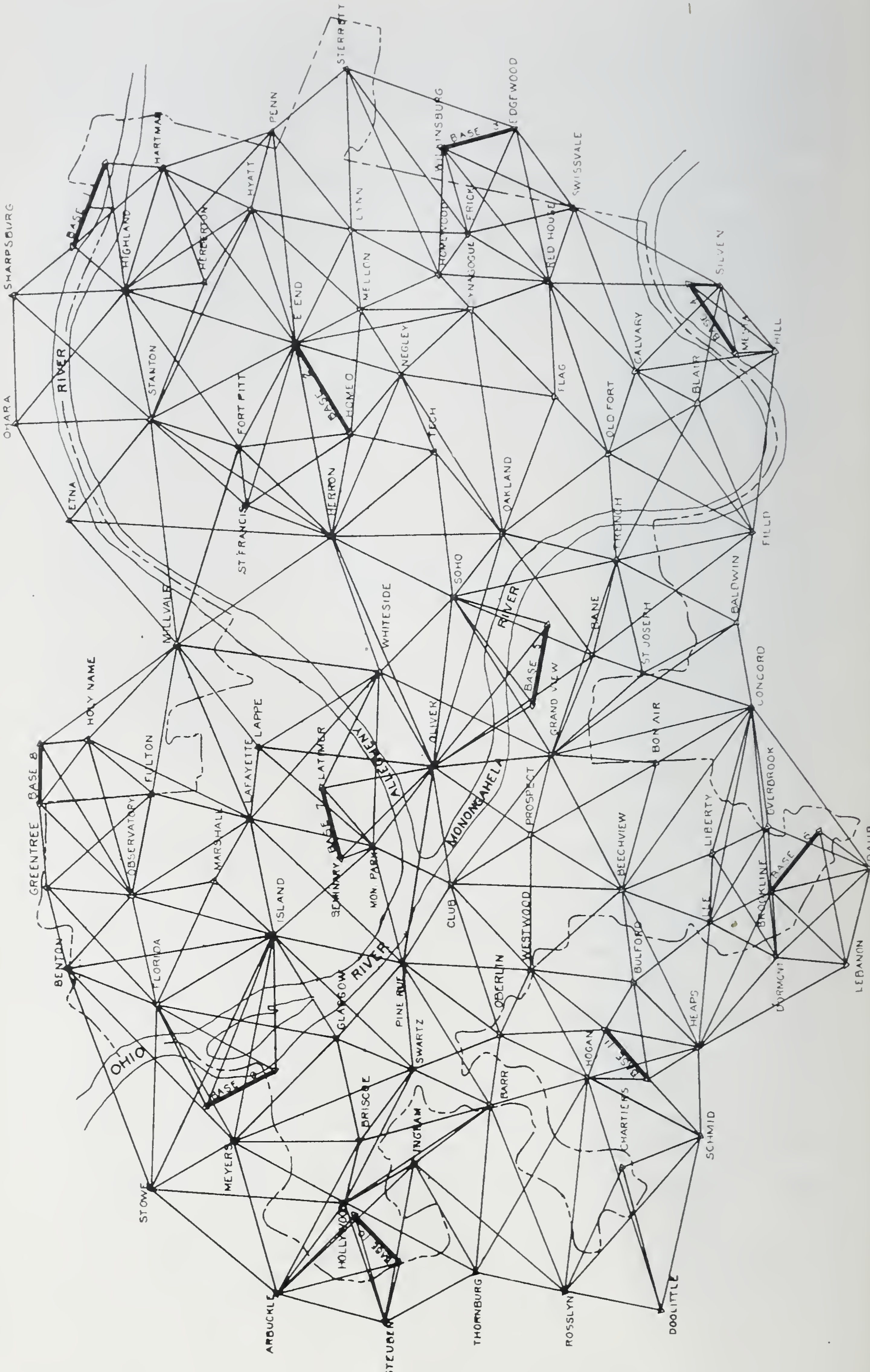

Fig. 1. Triangulation.

Co-ordinates and Azimuth. The Pittsburgh triangulation is being computed upon two co-ordinate systems. The geographic system establishes latitude and longitude values for all triangulation station positions, and also astronomic azimuths.

Geographic position is determined by accepting a mean of the position values of three United States Geological Survey stations which have been incorporated in the city triangulation. The rectangular co-ordinate system has its origin and reference meridian at North latitude 40 degrees and 26 minutes and West longitude 81 degrees. The exact intersection falls in the Monongahela River west of the Smithfield Street bridge. This is, of course, unimportant, as every point in the triangulation may be used as a reference or origin from which to redetermine every other point. The theoretical origin is assigned a value of 100,000 feet North and 100,000 feet East, so that all plane co-ordinates in Allegheny County will have plus values.

Azimuths for the plane system are carried throughout from the reference meridian of 81 degrees longitude. Disagreement between plane and astronomic azimuths increases east and west of this meridian at the rate of approximately 40 seconds per mile. Observations upon Polaris for azimuth were made at two different points in the triangulation scheme, and a mean value taken.

Accuracy. It was believed desirable at the beginning of the survey to make the triangulation of such an order of accuracy as might be considered sufficient for years to come. Accuracy of triangulation is largely judged by the size of the triangle closures, the base-to-base discrepancies, and the probable error of an observed direction. Investigations were made as to the precision attained in comparable city surveys such as New York, Cincinnati, Richmond, Va., etc. Based upon the experience of these and other cities, and appreciating the fact that city survey methods are constantly tending towards increased precision, it was decided that the Pittsburgh scheme should be executed with the highest practicable degree of accuracy. Specifications were accordingly adopted which require that discrepancies in length between measured bases shall not exceed one part in 100,000. This is to say that between any two base-lines, the computed length of one base as carried through the triangulation from the other must check the actual length of the second base by 1 : 100,000. For a base one

mile long the allowable error is about five-eighths of an inch. Triangle closures were limited to an average of 1.5 seconds, with a maximum closure not exceeding 4.0 seconds. The base-lines themselves are measured with a probable error not exceeding 1 : 500,000.

Planning for Accuracy. Proper planning for a specified degree of accuracy requires consideration of the principal expected sources of error. Triangulation errors originate in the measurement of bases and in the measurement of angles. Of angle measurement, which is the greater source of error, those factors which are external to the instrument are the most troublesome. With a given instrument, a certain program of observation will be found productive of the greatest accuracy practicable, and this program may be depended upon to give the same standard of results in the hands of any qualified observer. Errors arising from refraction and disturbed signals are not so predictable.

In the Pittsburgh triangulation there are many sights of less than a mile in length, these occurring usually within the city itself. To secure the required triangle closure it is desirable that each angle of a triangle be measured with an accuracy approaching ½ second. When it is considered that an angle of ½ second is subtended by approximately ⅛ inch at a distance of one mile, the difficulties of erecting and sighting signals within this limit become apparent. One of the chief sources of error is phase, or uneven illumination of the signal at the time of sighting. The observer unavoidably centers the apparent image, which is that part of the signal having strongest illumination. To overcome this, signal rods of triangular cross-section are employed, these being oriented anew so as to face each successive instrument station. Flagpoles, cupolas, etc., which have been customarily used in similar triangulation were avoided, resulting in the elimination of eccentric instrument stations necessary when such existing signals are used. Precautions were also taken to reduce the chances of horizontal refraction, which occurs when lines of sight pass close to heated buildings, smoke-stacks, or even hillsides. These latter difficulties, in the Pittsburgh district, are obvious.

The accuracy introduced into a triangulation scheme by the measurement of a base-line is rapidly dissipated as this measured length is carried through a number of triangles. This loss of accuracy bears a

definite relation to the number of triangles through which the length is carried, and to the shape of the triangles themselves. Given a certain standard of accuracy in angular measurement, the base-to-base checks will be better or worse in proportion to the number and shape of the triangles intervening between base-lines. Experience has shown approximately what this loss of accuracy is and indicates the approximate position for base-lines to obtain a certain desired accuracy. The probable strength of a particular chain of triangles, for the purpose of computation of lengths, is denoted by the expression R_1. The amount or summation of the factors entering into the formula representing this expression should not exceed 25, for an accuracy of 1 : 100,000. The average value of R_1 between the Pittsburgh bases equals 19. Eleven base-lines were employed to control the 103 stations and the 100 square miles of the triangulation of the city proper, no station in the scheme being more than three figures removed from a measured base.

Location of stations and base-lines was made by thorough field reconnaissance. This reconnaissance was made graphically, by the plane-table method, all possible sights between stations being drawn upon the sheet as the stations were visited. After rejecting those sights which were not essential to the scheme, or were undesirable because of probable smoke interference or horizontal refraction, the strength of figures was computed. A special effort was made to locate all stations either directly upon the ground or upon the roofs of permanent buildings, eliminating for the purpose of reduced cost and increased accuracy the building of temporary towers for elevation of the instrument (See Fig. 2). The selection of base-line sites was sometimes difficult. It was desirable that each base be at least 0.75 miles long, preferably straight, of reasonably low grade; and, furthermore, so situated that its incorporation into the triangulation scheme could be accomplished without undue expense or loss of accuracy.

Field Procedure. Upon completion of the reconnaissance, all stations were marked with suitable monuments. These consisted of bronze castings, three inches in diameter, screwed to iron pipes set in concrete piers three to four feet in length, and protected by cast-iron boxes with lids. All monuments are referenced to nearby objects so that they may be quickly located.

Observation of angles has been accomplished by the use of both the direction type and the repeating type of theodolite. The selection of the particular instrument has, as far as possible, been dictated by the character of the station to be occupied. In general, experience has indicated that the use of the direction instrument is preferable, satisfactory results being secured with less expense than with the other. During the latter part of the city observing and upon the county work, now in progress, the repeating instrument has been employed only where the instrument support was not stable enough to insure good results with the direction type. The direction instrument used is a Bausch & Lomb theodolite having an eight-inch horizontal circle

Fig. 2. Two Views on Chimney of Swisshelm School.

and reading by micrometer microscopes to two seconds (See Fig. 3). Two repeaters were available, one being manufactured by the Buff & Buff Manufacturing Company, and one by the Bausch & Lomb Optical Company, both reading to 10 seconds on eight- and seven-inch circles, respectively. In using either type, the instrument is kept shaded from the direct rays of the sun and sheltered from the wind by large umbrellas or tents (See Fig. 4).

The signal rods are of a special design, as has been indicated. They are triangular in section, from 8 to 12 feet in height, and about five inches across the face. For the longer sights of the county tri-

angulation, rods with seven-inch faces are used, with flags attached to aid in locating them (See Fig. 5). The bottom of the rod is fitted with a tapered iron shoe with a sharp point which exactly fits into a hole in the center of the bronze cap of the station monument. The face is painted alternately red and white in one-foot bands, and the rear sides are black. Since the center of the face is the observing center of the signal, centering the visible image by the observer (the black sides are not visible) results in uniformly accurate pointings. The

Fig. 3. Direction Instrument Used by Observing Party.

maximum viewing angle of the rods is about 60 degrees. Beyond this limit, it is necessary to re-orient the signal. For this purpose the upper end of the rod is rounded to fit into a metal collar by which it is guyed into the proper vertical position with wires and turnbuckles. Orientation is easily accomplished by rotating within this collar.

It has become increasingly the practice, on this survey, to employ lights for signals. Special six- to eight-volt automobile spot-lights are

fitted in boxes provided with means for directing the beam along the line of sight, and connected to 150-ampere-hour storage batteries (See Fig. 6). Signals of this sort are employed for night work and are, also, especially useful in daylight observing for penetrating smoke and haze and for sights where, due to dark or neutral backgrounds, the rods are not readily visible. It is certain that the use of such signal lights results in greater progress, as time is utilized which otherwise would

Fig. 4. Observing Party Protected from Wind and Sun.

be wasted in waiting for favorable atmospheric and visibility conditions; it is also believed that the use of the lights effects a lowering of unit costs, in spite of the increased attention necessary to operate the lamps.

The instrumental program for the direction theodolite consists of 16 sets of readings, each set being made up of one pointing with the telescope direct and one with the telescope reversed. The initial read-

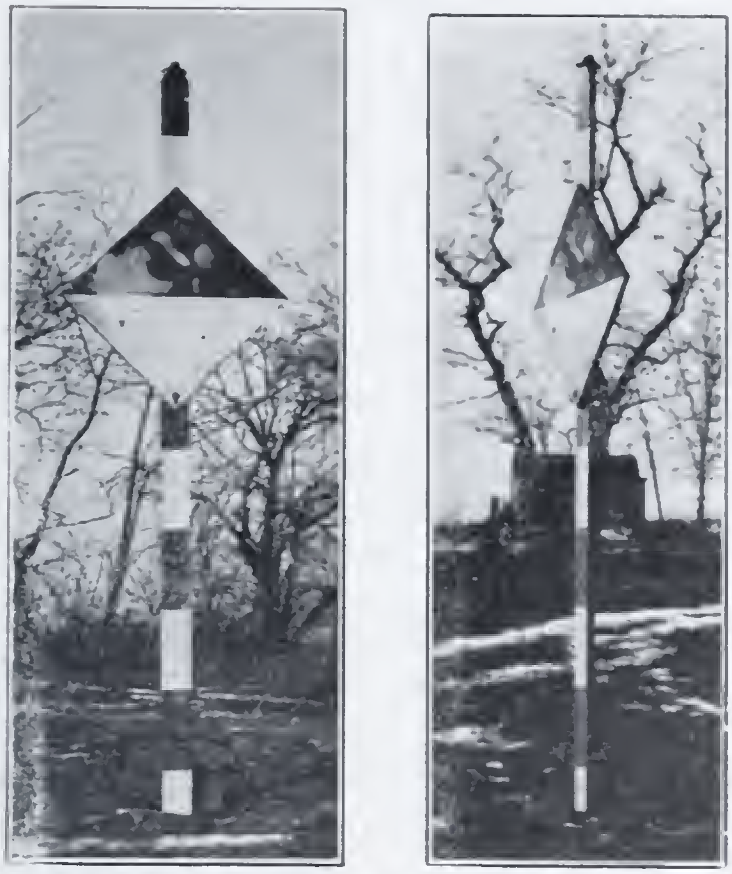

Fig. 5. Two Views of Triangular-Shaped Rods Used as Signals.

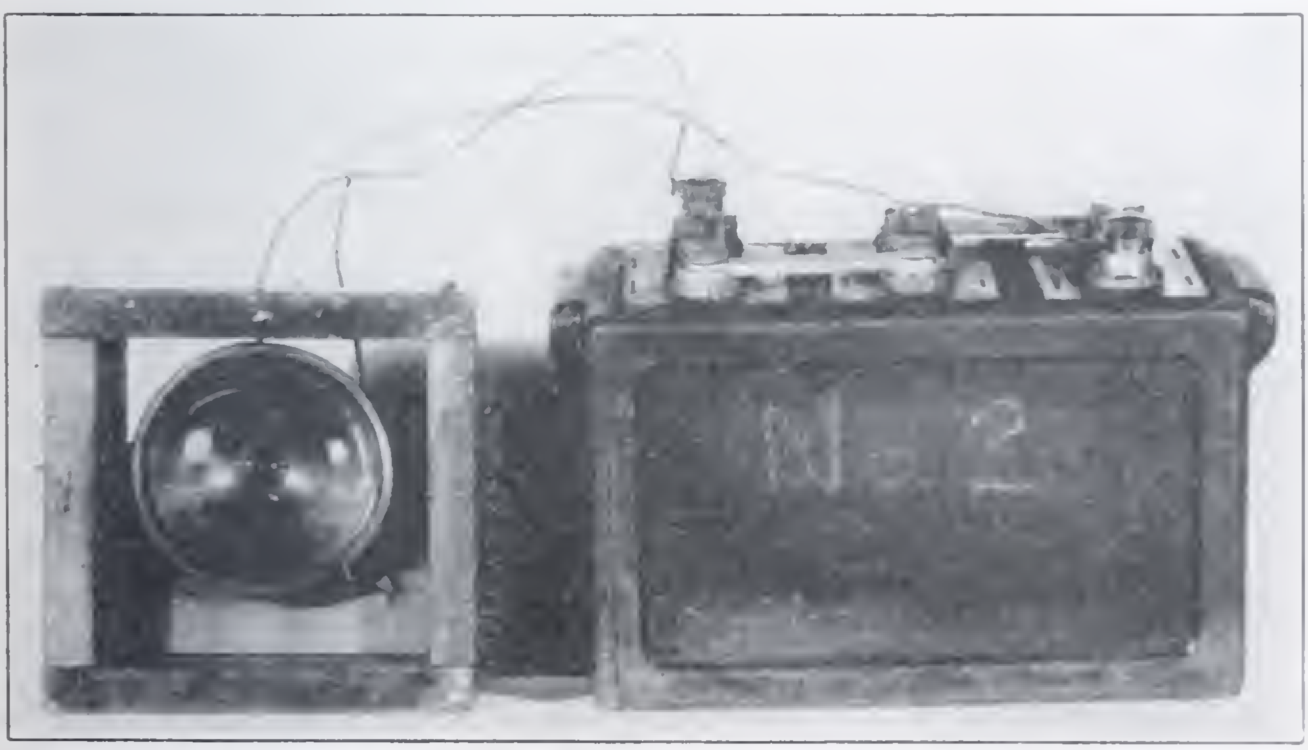

Fig. 6. Signal Light with Storage Battery.

ings for the sets are in all cases evenly distributed over the circle. The program for the repeating instrument employs from six to eight sets for each individual angle; a set in this instance being 12 repetitions—six with the telescope direct, and six with the telescope reversed.

Base measurement has been carried on simultaneously with angle observing, in order that preliminary lengths might be computed and ample time allowed for frequent standardization of tapes. The principal item of base measuring equipment is, of course, the tape. This has proved, in the present survey, to be the most troublesome, as will be discussed later. Original tape equipment consisted of two 50-meter invar tapes and one 50-meter steel tape. Six additional steel tapes of similar length were secured later. Further items were spring balances graduated in kilograms, tape stretchers, portable tripod supports for tape-end contacts, accurately calibrated thermometers, etc.

Upon all bases measured with the steel tapes, the hours between midnight and six a. m. were selected in order to secure more uniform temperature and consequently more accurate tape-temperature determinations. Since many of the bases are upon streets or railroads, night measurement has also been advisable because of less traffic interference. Most of the measures, being over paved streets, were made with the portable tape supports, or bucks. Wooden stakes, two by four inches in section, were used as supports in fields or other open ground where stakes could be driven. The base party consists of from 8 to 10 men. Two men make forward contact, one man stretching the tape and the other making and checking the forward mark; one man attends to the middle tape support; two more give tension and contact to the rear end of the tape. A levelman and one rodman determine elevations on all tape supports. Additional helpers are required for night work and to guard the tape against traffic interference.

Meter tapes are used for all base measurements because of the fact that the United States Bureau of Standards at Washington is equipped to standardize meter units about three times as accurately as feet. The 50-meter length is best adapted for base use, being about 164 feet long. All tapes were standardized for various conditions of support, and for a standard tension of 15 kilograms (about 33 pounds). Thermal coefficients for all tapes were determined by the Bureau over a range of 15 to 20 degrees C.

It is a matter of common knowledge that invar has a coefficient

of expansion only 1/25 as great as that of steel, and for that reason its use would seem to be preferable for base measurement. The difficulty is that invar is a less stable metal than steel. Without giving a detailed record of the action of the various tapes as shown by different standardizations during the survey, it may be mentioned that the invar tapes purchased by the city in 1914 have shown minus coefficients in recent tests—that is, they have shortened with increases of temperature and have shown wide variations in absolute length. Under the most favorable conditions, invar will tend to kink and develop slight bends and warps which will operate to shorten the tape. When this tendency becomes abnormally great and when minus and variable coefficients occur, it is evident that the physical structure of the metal is too unstable for practical use. Inquiry has not developed a source of supply for invar tapes that are satisfactorily guaranteed against such gross defects. Therefore, the demands for progress on the survey program have necessitated the use of steel tapes. Such tapes are capable of results well within the desired limits, and have been employed in spite of the difficulties of accurate determination of tape temperatures, necessity of night measurement, etc.

Each base has been measured a minimum of six times, a different tape being employed for each measurement.

In connection with the discussion of bases and base tapes, it may be of value to give the experience of this Survey in regard to testing and standardizing steel tapes. Six 50-meter, steel tapes were sent at one time to the United States Bureau of Standards for determination of absolute lengths and thermal coefficients. The tests for lengths and coefficients were made on a steel bench, the length of which is correct within about one part in 300,000. The coefficient of the bench has been determined and checked several times during the past few years. The lengths of the six tapes were compared directly with the length of the bench, at a temperature of 27 degrees C.; then, with the tapes still in position on the bench, the room temperature was lowered to 13 degrees C., and the difference between bench and tapes noted. The differences were also noted at a high temperature of 31 degrees C. From these observations, and knowing the correct coefficient of the bench, the coefficient of each tape was computed. The tape coefficients figured from this test averaged 0.0000132 per degree C., or 14 per cent. greater than for normal steel, which is 0.0000116 per degree C.

Computation of the field bases on which these tapes were used, with an average of more than five measures per base, showed unduly large discrepancies between the measures. An inspection of the results seemed to show that, as a rule, the higher the temperature the greater the length, leading to the conclusion that the coefficients of expansion, as given by the tests, were too large. Therefore, in an attempt to secure a temporary coefficient for preliminary use, a separate coefficient for each base was figured, assuming that all the separate tape coefficients would be of the same numerical value. The computations were made by two computers, working independently. The mean value, determined by assigning weights to the different values for the various bases, was 0.0000116, which is the average for tape steel. Using this new coefficient, and the corrections for absolute lengths which were refigured using the new coefficients, the base lengths were refigured and the new results showed satisfactory agreement among the various tapes.

Upon completion of the field work on the bases, the tapes were sent back to the Bureau of Standards for new length tests and redetermination of thermal coefficients. On this test the Bureau was requested to:

1. Determine all lengths on the geodetic comparator instead of the steel bench.

2. Determine length corrections at a room temperature of 20 degrees C. (68 degrees F.), or under, since this temperature would be nearer the actual temperatures encountered in the field.

3. Determine the coefficients on the geodetic comparator by fundamental tests—that is, to observe the actual difference in lengths at maximum and minimum temperatures.

The new coefficients, obtained in this latter test, averaged 0.0000120, or, assuming these coefficients as correct, the original values furnished by the bench test were in error by 10 per cent.

Astronomic azimuths have been observed at two stations on opposite sides of the city triangulation scheme, the results being checked by azimuths carried through the connecting triangles. The regular instrumental equipment employed on angular measurement was used for this, with the addition of a very sensitive striding level for determining the inclination of the axis of the telescope. A sidereal watch,

compared daily with the sidereal clock at the Allegheny Observatory, was used.

Computations. The first step in computation is the testing of triangles for angular closures and sine-to-side proportions, this test being based on the trigonometric theorem that in any triangle the sines are proportional to the opposite sides. Actual lengths are, of course, not known; but in a figure of four overlapping triangles, such as a quadrilateral, it is possible to make this test without knowing them. This proportion test is applied to all figures regardless of closures, but it is especially useful in locating errors where the angular closures are high. The proportion test is, however, not always an accurate index of errors, its usefulness being limited by the type of figure and size of angles involved.

Bases are computed immediately after measurement in order to test the accuracy attained. The various corrections applied to the field measures are, inclination, temperature, absolute length (pull and sag), and reduction to the sea-level and to the 1000-foot-level planes. Each individual tape length is corrected separately for inclination and absolute length. The temperature correction is applied to the entire base for an average temperature, and the plane corrections applied to the final mean of all the measures for any one base. In order to simplify computations, a special table has been compiled for inclination corrections to 25-meter tape lengths.

After the several measures for each base have been computed, the results are averaged and the probable error determined. It was desired to establish the base lengths with a probable error not exceeding 1 : 500,000. This, however, does not mean that the actual error is within that limit. For instance, if there were a constant mistake of one kilogram in the tension applied to the tape, the results might agree very closely, but the actual length still be considerably in error. The probable error is simply a mathematical value derived from the theory of least squares, and is a useful means of comparison. It may be said that, if everything connected with the base measurement is fundamentally correct, the actual error is not likely to be greatly at variance with the probable error.

After all triangles have been satisfactorily closed and base lengths computed, the next step is the least-squares adjustment. This adjust-

ment is made to remove all angular discrepancies; to make the sines proportional to the opposite sides; to insure that each triangle side will check for length, from whatever base it is computed; and to make the sum of the squares of the corrections a minimum. This latter requirement is based upon the theory of least squares—that is, that the most probable value from any set of observations is that value which will make the sum of the squares of the residuals a minimum.

In the Pittsburgh city scheme the entire net is divided into seven major adjustment divisions. This was found advisable, because any attempt to handle the entire scheme as a unit would result in computations of such unwieldy proportions as to be difficult of solution. Because of the fact that the triangulation itself is of a high order of accuracy, and because considerable thought was given to determining the best lines at which to break the adjustment, it is believed that no appreciable amount of accuracy has been lost because of the system of section adjustment. In order to make the entire net geometrically consistent, all lines and angles occurring in previous adjustments are held fixed.

The condition equations for removing discrepancies are of three types:

1. Angle equations, which remove the closures from the triangles and make all triangles total exactly 180 degrees.

2. Sine or side equations, which make all sines proportional to the opposite sides.

3. Length equations, which remove the length discrepancies between bases and insure that any side will check for length no matter from which base it is computed.

The unknown quantities in these equations are the corrections to the angles of the triangles which will satisfy the above-mentioned conditions. The absolute terms in the equations are the triangle closures, the sine discrepancies in the figures, and the base-to-base length discrepancies.

These condition equations are transformed into normal equations, at the same time inserting the additional condition that the sum of the squares of the corrections shall be a minimum. The normal equations are then solved by the Doolittle method. The corrections obtained are inserted back in the triangles, and, if the solution has been properly

executed, all triangles will close exactly 180 degrees, all figures will be of correct proportions, and the lengths will check through from base to base. The quality of the field work is then tested by obtaining the probable error of an observed direction, the average and the maximum correction to a direction.

To illustrate the amount of labor involved in one of these adjustments, it may be said that the largest Pittsburgh section has 82 condition equations with 132 unknown quantities. All seven adjustments have 393 equations with 700 unknowns.

After the entire net has been made rigid by a complete adjustment, the triangles are all computed and lengths obtained for each side. The observed azimuths are computed, brought to a central point, corrected for convergence of meridians, and averaged, so that bearings and co-ordinates may be determined. Having a starting azimuth, and geometrically perfect figures with all angles and lengths known, the rectangular co-ordinates are figured.

Before computing geographic co-ordinates a new set of distances is obtained, using the base lengths reduced to sea-level. With these new lengths and a true azimuth, the latitudes, longitudes, and geographic azimuths are computed based upon the Clarke spheroid, this spheroid having been adopted by the governments of the United States, Canada, and Mexico for similar computations.

Progress. At this date all of the field work on the city triangulation has been completed, including angular observing, base measurement, and astronomic observations. It is known, however, that from time to time, as the office work progresses, it will be necessary for an observing party to reoccupy some of the stations in order to lower occasional large triangle closures. All bases have been transferred, where this was necessary, to the regular stations. The office work is approximately 60 per cent. completed, including four of the seven major least-squares adjustments.

The triangulation of Allegheny County, which is similar in character to that of the city and which is being executed by this department, has been started. The reconnaissance for 242 square miles is complete. Approximately 79 station monuments have been set and observing completed on six stations.

Significant Data. The Pittsburgh triangulation includes 103 stations, 68 of which are ground stations, 35 being on roofs of buildings, etc. The area within the net itself is approximately 78 square miles and the area controlled by the triangulation is about one hundred square miles. Of the 11 bases, five are direct triangle sides, while six were required to be transferred to the regular stations. The significant figures on the adjustments so far completed are as follows:

TABLE I. ADJUSTMENTS AND DISCREPANCIES

Summary of adjustments, numbers 1, 2, 3, 4, 5, 6, and 15

Total number of triangles	116
Total number of directions, or unknowns	246
Total number of condition equations	121
	Inches
Average triangle closure	1.45
Maximum triangle closure	4.40
Average correction to a direction	0.53
Maximum correction to a direction	2.40
Probable error of an observed direction	±0.64

Base-to-base discrepancies

From	*To*	*Discrepancy*
Base No. 1	Base No. 2	1 part in 200,800
Base No. 2	Base No. 5	1 part in 103,000
Base No. 5	Base No. 7	1 part in 142,000
Base No. 5	Base No. 4	1 part in 300,000

It is estimated that more than 50,000 instrumental pointings have been made during the measurement of field angles, with about the same number of circle readings.

PRECISE TRAVERSE

Description. Precise traverse is logically a part of the triangulation system, as its purpose is simply to furnish additional monumented points along the streets, where they will be more available for every-day use than the widely scattered and sometimes inaccessible triangulation stations. Such traverse is essentially a series of second-

or third-class connected base-lines, with the angles between these lines measured by triangulation methods. The co-ordinates of these traverse monuments are the actual bases for map work and for departmental and private surveys.

Accuracy Desired. The precise-traverse system is usually of a slightly lower order of accuracy than the triangulation itself, but, on the other hand, it should be accurate enough to control all ordinary surveys. Since the triangulation was designed to have a precision of 1 : 100,000, and as ordinary city surveys seldom exceed 1 :15,000 to 1 : 20,000, it was decided that an indicated maximum in the latitude and departure closures of 1 : 20,000 would be sufficient, with an average of 1 : 35,000 or better. In computing this closure it is assumed that the triangulation, after adjustment, is perfect; and all triangulation co-ordinates are held fixed, the angular and linear discrepancies of the traverse being distributed between triangulation stations. This limit of accuracy compares favorably with other cities, where the allowed maximum closure is often much greater than 1 : 20,000, and the average seldom higher than 1 : 35,000.

Location of Traverse Lines. In executing precise traverse there are several conditions to be considered:

1. The lines should be evenly distributed.

2. They should be located on improved streets and in such places that the traverse stations are not apt to be destroyed.

3. The stations must be selected with the future use of the traverse in mind.

4. To obtain the necessary accuracy the lines should follow streets with low grades and with courses averaging 500 feet or more in length.

Furthermore, it is essential that the lines follow those streets upon which the city street-corner monuments are already in place. Effecting the best compromise between the above-mentioned conditions is often a difficult problem. Where only one condition can be satisfied, that of permanency of monumenting is given preference.

The approximate location of lines is first laid out in the office on a city street map so as to give even distribution of control. A field

reconnaissance party then goes over the area with authority to shift the line to suit the field conditions. The line is then monumented and properly referenced.

Field Procedure. Upon completion of the reconnaissance, the next step is the observation of angles. This is done by a four-man party using a 10- or 20-second repeating theodolite. The sight rods used are about seven feet long and are made of white pine, warping being prevented by strap-iron stays. The face of this rod is about one inch wide, painted white, with a ⅛-inch red stripe down the center. The iron point on the shoe of the rod is lined up with the center of this red stripe. The sides of the rod are painted black so as to prevent phase. Bull's-eye bubbles are attached for plumbing. Small tripods are carried by the rodmen for bracing the rod in position. The instrumental program is exactly the same as for triangulation, except that only one set of 12 repetitions is taken.

Traverse taping is similar to base-line measurement except that each course is measured only once and some of the refinements of base work omitted. One-hundred-foot tapes are used, with spring balances for tension reading in pounds, ordinary Fahrenheit thermometers for temperature, portable bucks for tape supports, and level and level rods (See Fig. 7). The party consists of five men, two at the front end of the tape, one at the rear end, one levelman and one level rodman. The bucks are lined in between stations by eye, except in the case of long courses, where a transit is used. Levels are obtained upon the bucks at the time of taping so that the inclined distances may be reduced to horizontal. Thermometers are read at every other tape length. At the last tape length of any course, which is usually an odd distance, the tape is independently read and recorded by the party chief and the instrument man.

Computations. The angles on all lines are first totaled to determine the angular error per station. If this is acceptable, the angular discrepancies are adjusted by establishing a mean azimuth at the intersections of traverse lines. Azimuths are brought to each intersection from all possible triangulation stations, by all possible routes, and each azimuth so determined is given a weight which is in proportion to the reciprocal of the square root of the number of intervening instrument

stations. A weighted mean azimuth is thus obtained for each intersection or junction point, and angular discrepancies distributed between adjacent junction points, or between junction points and triangulation stations. After the angles are so adjusted, azimuths are figured for each course and the bearings computed.

Distance-reduction computations for traverse taping are similar to triangulation-base reductions. It may be stated here that the absolute length corrections for the 100-foot tapes are obtained by compar-

Fig. 7. Taping on Precise Traverse.

ison with the 100-foot standard which has been established by this department in the basement of the City-County building. This standard was originally measured with two 100-foot invar tapes which had been standardized by the Bureau of Standards, and was later checked by two 100-foot steel tapes tested by the Bureau of Standards.

After bearings and distances have been computed, rectangular latitudes and departures are figured for all courses, and the lines tested for closing discrepancies between triangulation points. If all

closures are within satisfactory limits, the latitude and departure discrepancies are removed by a junction-point adjustment similar to the azimuth adjustment. In this case co-ordinates are determined for each junction point by all possible routes and weighted mean values established, the weights being proportional to the reciprocal of the square roots of the distances. Intermediate latitudes and departures are then adjusted in straight proportion to the distance between adjacent junction points or triangulation stations, and co-ordinates for all stations computed.

Significant Data. The progress to date on the city precise-traverse scheme is approximately one hundred linear miles, most of this being in the eastern part of the city. Several sections of the traverse in this portion of the city were run before the triangulation had been established and, consequently, additional lines will be necessary in this area in order to tie the old traverses to triangulation stations. Since final triangulation co-ordinates are not yet available, it is impossible to state the exact closing discrepancies of the traverse. However, judging from loop closures and from closures based upon preliminary triangulation co-ordinates, it is believed that a large majority of the lines will be within the prescribed limits of accuracy.

Due to the rugged topography of Pittsburgh, its crooked streets and uneven grades, it is expected that double chaining on many of the lines will be necessary in order to obtain the desired accuracy. Because of the many short sights it will also be necessary to "throw in" azimuth control lines at frequent intervals. This is accomplished by observing nearby triangulation stations visible from traverse set-ups, then revisiting the triangulation stations and reading angles to the traverse points.

In the county geodetic survey the precise-traverse and level lines are usually identical, and the traverse monuments are used as bench-marks. The reconnaissance has been completed and monuments set on about fifty miles of the county traverse scheme.

Possibility of Errors. For the benefit of those who anticipate using the precise-traverse results, it may be stated that traverse is not capable of a rigid mathematical proof of accuracy, as is triangulation; and, in spite of all the precautions that can be taken, there is the pos-

sibility that compensative minor mistakes in distances or angles may slip by undetected. Engineers who discover such errors should report them to this department so that corrections may be made and the computations revised.

PRECISE LEVELS

Description. Precise levels are the foundation of the vertical-survey system as the triangualtion is of the horizontal. Precise-level bench-marks furnish elevations of known accuracy from which other level surveys may be started. The precise elevations are especially useful in the design and construction of major improvements such as viaducts and bridges, sewerage systems, water-distribution systems, railroads, tunnels, etc.

Leveling in 1912. Pittsburgh is unusually well supplied with precise-level bench-marks, having probably as complete a system as any city in this country. This network of levels run in 1912 by the Bureau of Surveys included 435 miles of double-run levels over permanent bench-marks. All bench-marks were marked with bronze castings set in masonry, and all the sections were within the standard limits for this class of levels. The criterion for acceptable accuracy is that the two runnings over any one section, one backward and one forward, shall agree with each other within $0.017\sqrt{M}$, in which M is the length of the section in miles.

Field Procedure. The level equipment used consisted of a Bausch & Lomb coast survey model precise level. The essential features of this type are:

1. The metal used is invar, having a low coefficient of expansion, thereby reducing distortion in the instrument due to changes in temperature.
2. The sinking of the level bubble into the telescope tube, so that the bubble itself is very close to the line of collimation, and any distortion which does occur thereby has less effect upon the parallelism of bubble and line of sight.
3. A micrometer screw at the eye end of the instrument for bringing the bubble exactly to the center during readings.
4. The addition of a secondary telescope with mirror and prisms for viewing the level bubble.

5. A very sensitive level bubble usually ground to an arc of from two to five seconds per division.

The rods used are of the wooden type, T-shape in section, with the face about three inches wide. The graduations are in yards, the smallest graduation being 0.01 yard, and this being divided by estimation into 10 equal parts, or thousandths of a yard. The yard divisions are marked by silver plugs inlaid in the wood. Each separate yard is marked by a different color, thereby reducing the chances of blunders in the yard readings. The rod is supplied with a thermometer and has a circular bubble for bringing it into a vertical position. Special portable iron turning-points are carried by the rodman and used as supports for the rods (See Fig. 8). Additional equipment used by this party consisted of an umbrella for sun protection, folding windshield, specially printed note forms and standardized tape for measuring the rods.

Future leveling executed by this survey will be done with the newer type of rods which have independent invar strips for the fine graduations, thus reducing the errors due to the changing lengths of the wooden rods. The field program is briefly as follows: The instrument is set up and leveled approximately by the small circular bubble. It is then pointed to rod "A" (the same rod is always sighted first whether it be in the backsight or foresight position, to reduce errors due to settling of the instrument), and the bubble brought to the center by means of the micrometer screw. While the bubble is exactly in the center—this being viewed through the secondary telescope with the left eye—the three horizontal wires are read and recorded. Immediately thereafter the instrument is pointed to rod "B," the bubble brought to the center and the three horizontal wires read. The recorder checks the mean of the three wires and notes the agreement between this and the middle wire. In cases where the discrepancy, or lack of agreement, exceeds a certain amount the reading is repeated. With an experienced observer this discrepancy rarely exceeds the allowable limit. Before leaving a station, the recorder also computes the two half intervals, notes their agreement, and completes the backsight and foresight distance totals.

Some of the features which differentiate precise leveling from ordinary leveling are:

Fig. 8. Precise-Level Party and Equipment.

1. Measurement of rods at regular intervals to determine absolute length.
2. Correcting rod lengths for temperature and humidity.
3. Adjustment of level at least once every day and determination of constant for correcting bubble error.
4. Making backsight and foresight distances on each "set-up" agree within a specified limit; and also making totals of backsight and foresight distances approximately equal for the section.
5. Protection of the instrument from sun and wind.

Computations. The Pittsburgh precise-level system has already been completely adjusted by the method of least squares, and elevations have been computed for all of the bench-marks. The datum used is mean sea-level as established by the United States Geological Survey. In some of the outlying sections of the city it has been found necessary to extend and amplify the 1912 survey for the purpose of supplying bench-marks at closer intervals for the plane-table surveys. In these cases the new lines are adjusted to the old elevations, this being held absolutely fixed. The method of adjustment is, in the case of a single line, simply to distribute the closing discrepancies in proportion to the distances. Where two or more lines intersect, forming junction points, the regular junction-point method of adjustment, similar to that for precise traverse, is used.

Bench-Marks. The type of bench-mark used on the 1912 levels is a flat bronze disk having a shank about four inches long. This disk is set into substantial masonry structures wherever possible. Where solid masonry is not available, the disk is set in a concrete monument 12 to 15 inches in diameter and three to four feet deep.

County Levels. The Allegheny County precise-level system has been started and approximately twenty miles of levels completed. It is expected that precise levels will be run over most of the improved roads with bench-marks at every road intersection, and at intermediate points. The county system will have two types of benches:

1. A bronze cap screwed onto an iron pipe and set in a concrete pier, this monument to be not only a level bench-mark, but also a precise-traverse station.
2. A bronze disk, similar to that used on the city levels, set in solid masonry structures such as bridge piers, culverts, etc.

TOPOGRAPHIC SURVEY

Description. The topographic map, which is being made of the incorporated area, is a definite and valuable result of the Pittsburgh survey. This map, as has already been mentioned, is a bird's-eye view of the ground. On it are shown to exact scale and position all streets, roads, alleys, curbs, retaining walls, steam and electric railroads, bridges, public, semi-public and industrially important buildings, streams, lakes, etc. The conformation and elevation of the surface of the ground are shown by means of contour lines. From the topographic map grades may be accurately computed, drainage areas may be scaled within a fraction of an acre, and excavation quantities computed. The Pittsburgh map sheets are published on a scale of one inch equals 200 feet, with a 2.5- and a 5-foot contour interval. The datum plane for contour elevations is mean sea-level, thus placing the maps upon the ultimate datum plane and agreeing with federal, state and other maps.

The publication scale of one inch equals 200 feet was adopted as best fitting the conditions imposed, which are:

1. The map scale must be large enough to indicate clearly and accurately all of the information desired to be shown.

2. The scale should bear a definite relation to the accuracy of field measurements, and, since the majority of the positions are located by stadia, and stadia distances are dependable only within one foot, the scale should be such that distances may be plotted and scaled to the nearest foot.

3. The scale of the map must be small enough so that the area covered by any one map sheet would be of such size that ordinary district improvement projects may be covered and studied upon one sheet, without the necessity of assembling and matching various adjoining sheets.

4. From an economic standpoint it is desirable to keep the scale as small as possible, in order to decrease the cost of the field work and of reproduction.

While the scale of publication is 200 feet, the field scale, upon which the maps are sketched in the field, is 165 feet. The purpose of this is the possible increase in accuracy of scale by the reduction, which is a part of the photographic process of publication, and the sharpening of lettering and other cartographic details and consequent im-

provement in appearance of the final published copies. It is of further advantage to make the field scale as large as is consistent with stadia methods for the purpose of making enlargements. It is, for instance, possible to make a better photographic enlargement to a scale of 100 feet by using an original copy on a scale of 165 feet than would be the case if the original were on a 200-foot scale.

Uses. One of the most constructive phases of city planning is the laying out of streets and thoroughfares in outlying districts in advance of development. In most cities this has not been possible because of the lack of information regarding the topography of these areas. It is, however, becoming increasingly the practice, as is evinced by the fact that in one state there is a statutory provision enabling cities to lay out streets and thoroughfares within five miles of their limits, but this permission is given only to those cities having accurate topographic information upon which to base their plans. Upon completon of the Pittsburgh map sheets it will be possible to do this sort of planning. Having worked out definite ideas as to the proper street system, reasonable plans can be shown to owners and subdividers who wish to place new plats on record. The city's planning, being logically based upon thorough information and study, will protect the public interest and will usually appeal to the subdivider also, even without the exercise of any legal authority to compel him to conform. At the present time, as new subdivisions come before the City Planning Commission for approval, the lay-out of the streets and lots is studied carefully, using the topographic map as a basis whenever it is available.

The map is also of great value in the selection of locations for bridges, tunnels, parks and boulevards, and an invaluable aid in the design of such improvements as sewers, harbor and river projects, etc. It is also helpful in establishing rates of assessments on the benefit-assessment plan, especially on such items as storm sewers and drainage projects.

Map Projection. In deciding upon the system of projection to be used on the map sheets, there were three conditions to be considered:

1. The projection must be such that the maps will always be in correct orientation—that is, the boundaries of each sheet should

always be true north and south, east and west, in order that the true azimuth or bearings of any line may be quickly scaled from the map.

2. The projection should permit of practically indefinite expansion.

3. In order to be joined correctly and easily to other maps, such as those published by the federal government, state, Interstate Commerce Commission, etc., the boundaries of each map sheet should be some even value of latitude and longitude, these values being co-ordinates based upon the North American Datum.

4. For ease and simplicity of ordinary distance, bearing, and position computations, the maps should have superimposed upon them a rectangular system of co-ordinates. A specimen sheet is shown in Fig. 9 (folding plate).

The projection which has been adopted meets all the conditions satisfactorily and is very simple to compute and plot. Each map sheet covers one minute of longitude and 35 seconds of latitude. Starting at the origin of rectangular co-ordinates—latitude 40° 26′ 00″, longitude 81° 00′ 00″—and making this point the common corner for four sheets, the lay-out was extended to cover the entire city. Knowing the geographic size of each sheet and having the origin to start from, the geographic co-ordinates of all the other corners were computed. Then, for convenience in plotting the sheets, the geographic co-ordinates of each sheet corner were converted to rectangular co-ordinates, and from these the dimensions of each sheet figured. It is to be noted that each sheet is 0.7 foot narrower across the top than across the bottom, making an extreme difference in sheet width from the northernmost sheet to the southernmost of 8.7 feet. The north and south distances do not vary by more than 0.1 foot. The formulas and arc lengths used in converting geographic to plane co-ordinates are given in Special Publication 71, of the United States Coast and Geodetic Survey, entitled "Relation Between Plane Rectangular Co-ordinates and Geographic Positions."

Preparation of Field Sheets. The map sheet used in the field on the plane-table board is of heavy white drawing-paper mounted upon aluminum. These metal-mounted sheets are used in order to prevent the expansion or distortion which occurs when ordinary muslin-mounted sheets are exposed to the weather. The sheet is plotted in

the office with geographic boundaries, even 1000-foot rectangular co-ordinate lines, triangulation points and bench-marks shown. The actual plotting of the co-ordinate lines is as follows:

A construction rectangle, 22.5 by 27 inches in size, is drawn on the sheet by means of a metal templet cut to exactly this size. The templet is used in order that the overall size of all sheets will be correct. Knowing the exact size of the sheet to be plotted, the offset distances to the sheet corners are scaled on right-angle lines from the corners of the construction angle. The sheet corners are then joined with straight lines, the resultant figure being theoretically a trapezoid, but for all practical plotting purposes a simple rectangle. The intersections of the 1000-foot co-ordinate lines with the map edges are then scaled from the corners along the edge lines, and these intersections joined. The triangulation and traverse stations are then plotted in their correct positions by means of rectangular co-ordinates. Before any sheet is allowed to go into the field the edges of adjacent sheets which have been previously worked are transferred to it.

Field Mapping. The plane-table party consists of three men. The topographer is chief of the party, operates the instrument, plots the stadia readings, and sketches the terrain. The recorder records all instrument readings, descriptions of turning-points and bench-marks, and computes elevations and distances. The rodman goes about over the area giving rod readings on critical points. The equipment used is a Johnson-movement tripod, a plane-table board, size 24 by 31 inches, a 12-inch telescopic alidade, a 14-foot stadia rod, stadia-slide rule, etc.

It is generally conceded that, in the hands of experienced operators, the plane-table method of taking topography is, from the standpoints of accuracy and cost, superior to any other method. Its chief advantage lies in the fact that the topographic details are sketched while observing the ground, any material blunders and mistakes being thus eliminated. Furthermore, a more accurate delineation of the surface of the ground is secured because of the fact that the contours are sketched while the party is on the ground. Comparative figures over a number of years have proved that the use of the plane-table results in lower unit costs.

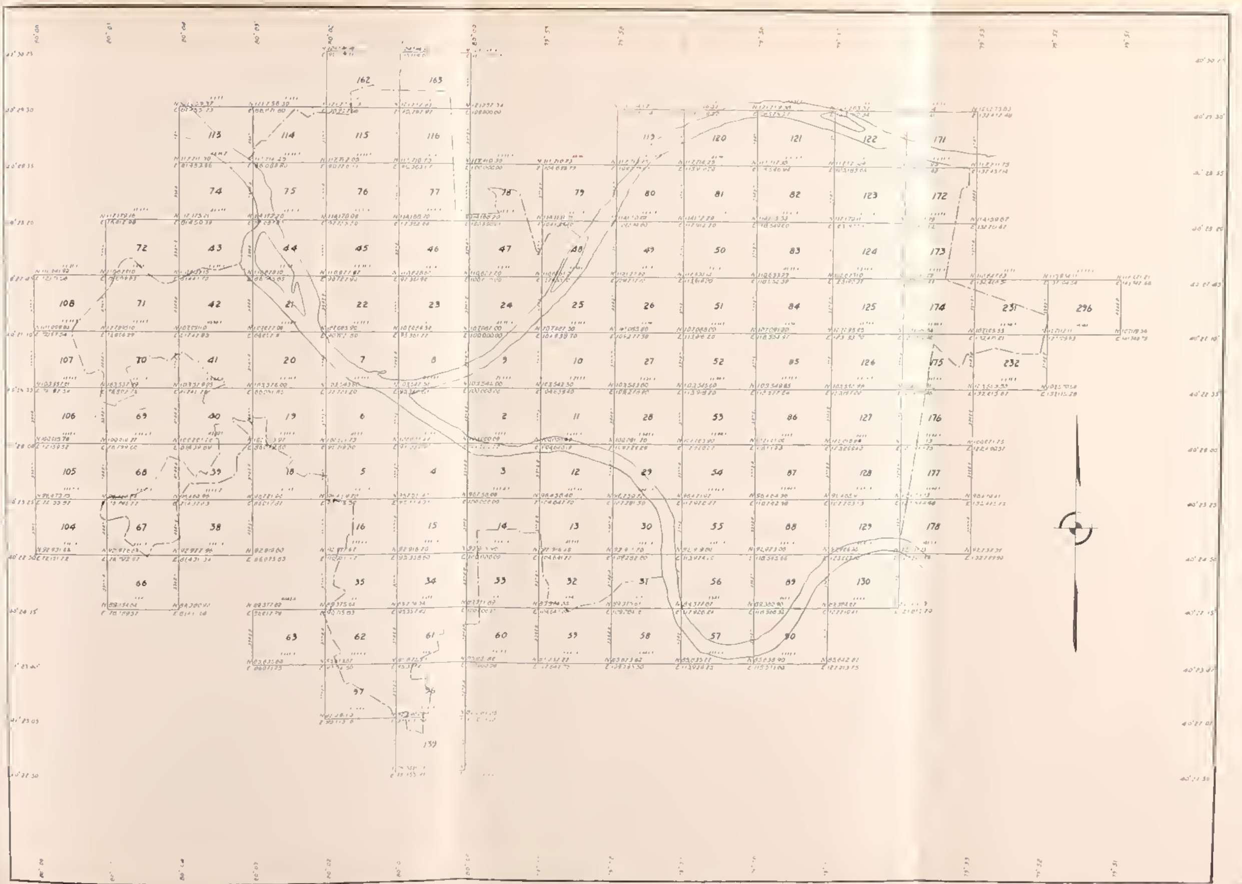

Fig 10. Lay-out Showing Arrangement of Topographic Sheets.

Fig. 9. Specimen Topographic Sheet.

Specifications under which the field parties work are briefly as follows:

1. Plane-table traverse closures must not exceed three feet for the first 1000 feet traversed, and two feet per thousand thereafter. In no case must the total closure exceed seven feet. Closures must, on the average, fall midway between control traverses and shall be distributed in proportion to the distance.

2. Levels carried by the plane-table shall close within one-fourth of the contour interval—that is, on reasonably flat country where the 2.5-foot interval is being used, the closure shall not exceed 0.6 foot, and on steep country such as rugged hillsides and bluffs, the closure shall not exceed 1.25 feet.

3. Instrument readings for distance, bearing, and elevation shall be taken with such frequency and the topographic details so sketched that:

a. Elevations taken from the contour map shall be correct within one-half the contour interval.

b. Horizontal distances between well defined points shall scale correctly within three feet.

Each map sheet covers an area of 0.59 square mile or about 377 acres. The average dimensions are 3542 by 4640 feet. The total city area scheduled to be mapped is in excess of 55 square miles, and includes 121 map sheets. The average number of "shots" per acre has been about 15, with about one instrument set-up per acre. The total progress accomplished to date in field mapping is 6.51 square miles, this comprising 10 complete sheets and seven fractional parts of sheets. The sheets completed are in widely separated areas, having been mapped for studies for specific improvements in those areas. Fig 10 (folding plate) shows the arrangement of topographic sheets.

The field maps are tested occasionally by means of random profile lines run with transit and level, each profile being plotted on the same sheet with similar profile scaled from the map. Such checks have indicated that the vertical and horizontal accuracy of the sheets is well within the limit specified (See Fig. 11). Another test on the general accuracy is the checking of the sheet edges, each topographer checking by random "shots" that part of the edge which has been transferred to his sheet from adjoining sheets previously mapped.

Checking Property. Upon completion of the field sheets, the next step is the office searching for property information. All available record plats of subdivisions, property atlases, etc., are first assembled. Then the distances between points, such as monuments, fences,

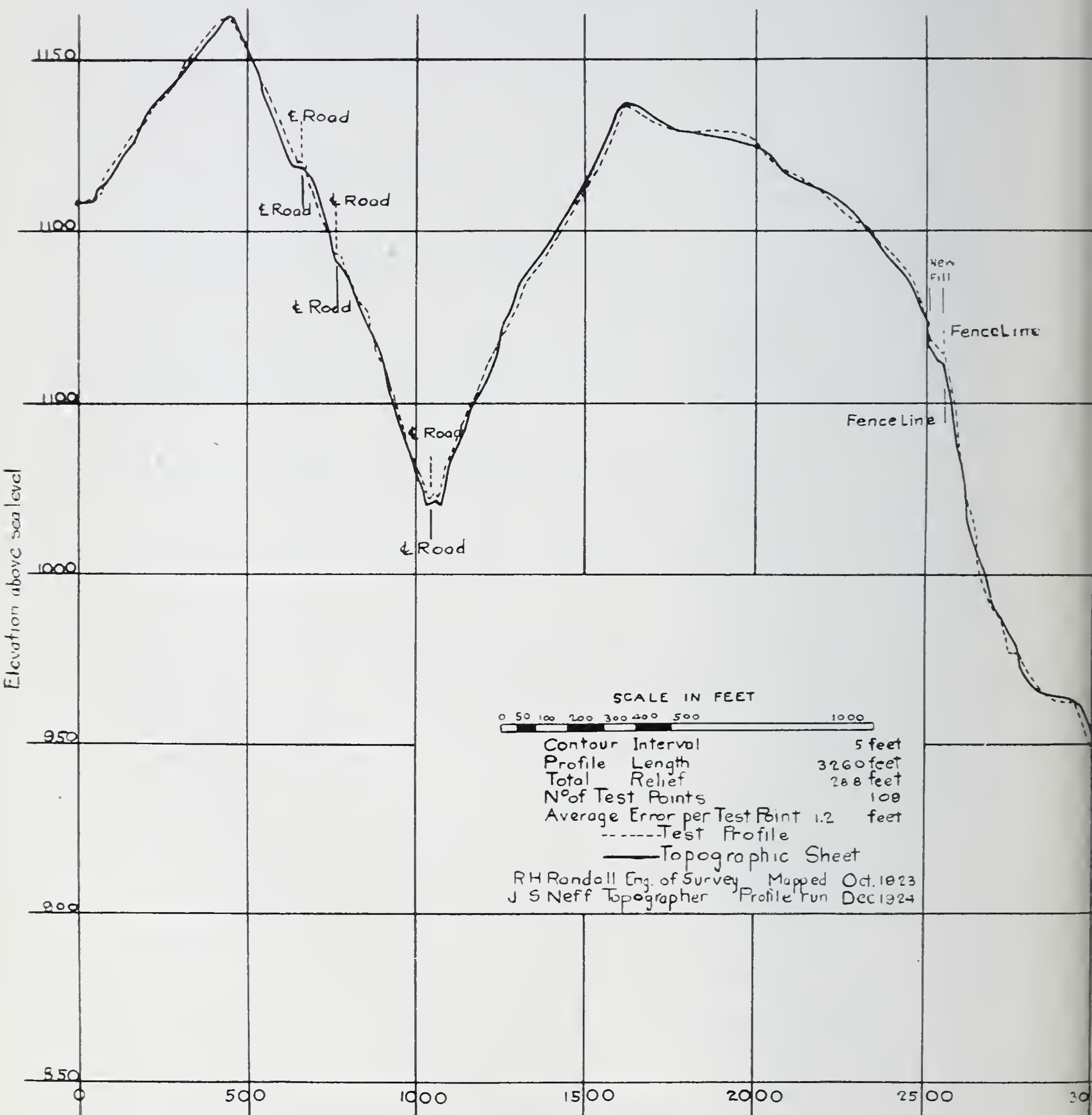

Fig. 11. Test Profile on Topographic Sheet No. 128.

street lines, block corners, etc., which can be identified upon the record plat, are scaled from the field sheets and compared with distances shown on the plat. In those cases where there are considerable

discrepancies between the scaled and recorded distances, the field sheet is returned to the field to be checked. When all identified lengths have been checked against the plats, these checked lines are used as a basis from which the recorded information on the remaining lines and corners are plotted. The property lines shown upon the sheets are the street and alley lines, boundaries of recorded subdivisions, boundaries of public property, including parks, playgrounds, schools, cemeteries, etc. In some cases the boundaries of large, privately owned, undeveloped tracts are shown.

For convenience in reproducing, a cover sheet or information tracing is drawn. This is merely a tracing of the cultural information on the field sheet and shows all streets, roads, alleys, boundaries of other properties, buildings, bridges, tracks, and all lettering to be shown on the reproduced map.

Reproduction. After completion, the field sheet is reproduced in four colors. Cultural information is shown in black, contours in brown, drainage in blue, and public property in green. The reproductions are to exact scale within the limits of paper expansion, and registration is correct at all points, the allowable registration error being 0.01 inch. Two hundred copies on light-weight paper of these four-color reproductions are printed on the initial order. In addition, ten copies are printed on "lenora" cloth for use in binding in atlas form. It is also expected that several copies will be secured showing the cultural information only.

The printing plates become the property of the city and are stored for use in printing future editions, and the making of revisions. Copies of the reproduced maps will be available for distribution to other city and county departments and to the general public.

The beginning of the survey, in the fall of 1923, was made under a handicap due to the necessity of obtaining immediate topographic information and the necessity of starting the control surveys. It was desired to do all plane-table mapping on the regular sheet lay-out with correct co-ordinates, so that each area mapped would be a unit of the final survey. Correct co-ordinated positions were obtained in the first area, in advance of the triangulation, by running precise traverses from the nearest government points having geographic positions on the North American Datum. These traverses were kept in correct orienta-

tion by means of frequent azimuth observations, and the co-ordinated positions checked with some former city secondary triangulation which had been tied to another government station in the northwest part of the city. The entire survey from the beginning has been planned so that possible future expansion into the metropolitan area would be easy and convenient. This scheme has now been adopted for the expansion of the city survey to cover the entire area of Allegheny County.

It is probable that the Pittsburgh survey will help to standardize the specifications and standards of accuracy for similar surveys in this country. It is believed that the triangulation and traverse surveys are of a higher degree of precision than has heretofore been obtained over any similar area. Certain instruments, formulas, and mathematical tables and charts have been devised or improved upon during the progress of the survey, and upon completion of the work this information will be published and made available.

The Department of City Planning acknowledges appreciation of the helpful co-operation which the various city and county departments, railroad officials, private engineers, etc., have given. In return for this assistance this survey has already been helpful in furnishing contour maps and other survey data to departments and individuals. A feature which has met with favor among engineers in Pittsburgh is the tape standard established in the basement of the City-County building.

It is strongly recommended that engineers practising within the survey limits make use of the precise triangulation and traverse stations for testing the accuracy of their surveys and co-ordinating such surveys with the city system. The advantages of this to both the city and the engineers are apparent.

PUBLICATION OF REPORTS

It is planned to publish reports giving detailed information concerning the various phases of the survey, designed for the convenience of engineers, as soon as the different divisions of the work shall have been completed. These reports of the city survey will take the following form:

Triangulation. A report giving a sketch of the triangulation net, station names, descriptions, co-ordinates, azimuths and distances.

Precise Traverse. A report giving the results of the traverse system, including description of stations, co-ordinates, distances and azimuths.

Precise Levels. A report giving the elevations and descriptions of all precise bench-marks within the city.

Similar reports for the work in the county, outside the city limits, will be published as the progress of the survey justifies such action.

SUMMARY

Briefly summarizing, at the end of the second full year, the Pittsburgh Triangulation and Topographic Survey has accomplished the following:

1. Completion of all field work necessary for the city triangulation scheme, which includes 103 stations with 11 base-lines. The least-squares adjustment on over sixty per cent. of this system is also completed. In the county scheme, 79 stations have been located and monumented covering an area of 242 square miles. Six of these have been occupied and observed.

2. In the field, 118 miles of precise traverse, controlling approximately twenty-five per cent. of the total area of the city, have been completed. In the county 50 linear miles have been completed for reconnaissance, controlling 30 square miles and referenced by 47 monuments.

3. Fourteen miles of precise levels, augmenting the old city system, have been run and adjusted, and 24 miles of the county system have been run.

4. Eighty-three miles of secondary levels, furnishing bench-marks for the plane-table parties, have been completed.

5. Six and one-half square miles of topography have been mapped in the field.

6. Reproduction on three sheets has been completed and a satisfactory and economical process evolved. Arrangements are now being made for the awarding of a contract for this work.

The survey of the City of Pittsburgh and Allegheny County are both being made by the Department of City Planning, City of Pittsburgh, under the supervision of the City Planning Commission, of which Morris Knowles is Chairman, and Frederick Bigger, James M. Clark, George S. Davison, Charles A. Finley, James D. Hailman,

A. J. Kelly, Jr., James F. Malone, and W. C. Rice are members, with Norman F. Brown, Director Department of Public Works, Allegheny County; Charles M. Reppert, Assistant Director Department of Public Works, Allegheny County; and Edward Schmidt, Division Engineer, Allegheny County Planning Commission, consulting as to the survey outside the limits of the City of Pittsburgh. The immediate planning and execution of the survey are under the direction of the writers, assisted by G. D. Whitmore, Geodetic Engineer, and M. Y. Poling, Topographic Engineer.

DISCUSSION

J. M. Rice:* I would like to ask whether it is proposed to tie in this system to existing city monuments and give us co-ordinates on those monuments?

U. N. Arthur: Yes, it is proposed to tie in all existing monuments with this system and give their plane co-ordinates.

J. M. Rice: It would be interesting to know how this compares in cost with similar work in other cities, such as Cincinnati and New York. Is it costing more or less, and how is it justified?

U. N. Arthur: It is rather difficult to compare the costs of our survey with those in the other cities named. The bases on which the surveys are made are entirely different. We are working on a scale of accuracy of 1 : 100,000, while in New York it was 1 : 25,000, which makes a considerable difference. The Cincinnati survey was conducted on a different system. Mr. Randall can perhaps answer this question more fully.

R. H. Randall: What Mr. Arthur has said about comparison of costs is very much to the point. Besides the question of the accuracy which it is desired to obtain, consideration must be given to the local conditions which will affect this survey in comparison with

*Consulting Engineer, Pittsburgh.

others. There is probably no section in this country which presents more difficulties in triangulation than does Pittsburgh. It happens that location of stations has been rather easy, the hills and prominent points occurring at such intervals as to fit in very well with our scheme; but the scheme itself has had to be governed by visibility limitations.

I have here some figures on comparable triangulation costs. In the New York survey, just mentioned, the cost was $415.30 per station. There were 146 stations occupied, and 183 stations of which the co-ordinates are published. The total cost was about $76,000. The accuracy obtained in New York is about 1 : 25,000. Triangulation in Cincinnati had a cost of $106 per station, and the accuracy is from one-half to one-third of what Pittsburgh is obtaining. In the survey of Richmond, Va., the triangulation cost per station was $105, and the accuracy 1 : 42,000. These are about all the statistics available for a comparison.

J. M. Rice: What is Pittsburgh's cost?

R. H. Randall: The direct labor cost is $255 per station, to which are to be added certain overhead charges, which can not be estimated very well before the work is entirely completed. It is believed that $280 will probably cover the cost per station.

J. M. Rice: What is the total cost to give us the map for the city of Pittsburgh?

R. H. Randall: I do not know that I can answer that question exactly at this time. The triangulation is substantially completed over the city's present area, and about 6.5 miles of plane-table mapping have been completed; but, although we have complete records of the unit costs of this work, it is not possible to be sure that they will apply to everything that remains to be done. The exact extent of the area to be mapped is also undetermined. Present plans call for about 115 map sheets, but this will obviously be extended as the city's growth shall require. Costs will also be largely influenced by the order in which different areas are mapped. Certain sheets will from time to time be demanded for the study of specific improvements, even

though these are in widely scattered localities and consequently entail increased mapping costs. Thus, while cost is an important factor, the necessity for the vital information furnished by the survey is the governing consideration. These three factors, then—the relatively small amount of unit costs yet available, the undetermined extent of the mapping, and the necessity of securing needed information even at the expense of the best economic procedure—make it practically impossible to give total costs at this time. The justification of our costs must rest upon comparisons with the unit costs of other similar surveys, when these are available, and upon the value of the completed work to the community.

J. Hammond Smith:* I would like to ask to what extent you found it necessary to take into account the curvature of the earth in these surveys?

R. H. Randall: The curvature of the earth is allowed for and is represented in the geodetic co-ordinate values. All of the triangulation statistics are to be published with two sets of co-ordinates, the geodetic and the plane. Not only has the curvature been considered in our basic computations, but distances for the traverse lines are corrected for their average elevation above sea-level.

W. E. Fohl:† Will both values be given at these points?

R. H. Randall: Both co-ordinate values will be given for all triangulation points, but only one set, the plane, will be published for the traverse stations.

J. M. Rice: It seems to me we are missing an important opportunity of putting on record here just what advantages this topographic survey will be to the municipal authorities and also to the individuals who have to make surveys or use them now; and, secondly, we ought to put on record quite clearly what it will not do. I think that is probably as important as the first. It will not do away with the necessity for a lot of engineering work of a surveying nature. I

*Professor of Civil Engineering, University of Pittsburgh, Pittsburgh.
†Consulting Mining Engineer, Pittsburgh.

think Mr. Randall or Mr. Arthur ought to go into that a little more in detail, because we are all interested in that phase of it.

U. N. Arthur: We all recognize the limitations of a survey of this kind. Shortly after entering the city service I was impressed with the necessity of some means of co-ordinating the various surveys, made by the Bureau of Surveys, in order that they might be of more permanent value. We hope by this system to have all surveys tied in with the triangulation scheme and co-ordinated, which will not only give a check on such minor surveys, but will make the data secured a permanent part of the city records.

The basic survey maps will furnish a sufficiently accurate basis to determine the feasibility of suggested new projects, especially for proposed new streets, bridges, viaducts, etc. It will also be possible to determine from the topographic maps the approximate cost of all contemplated new work. The main drainage systems can be studied and sufficiently close approximations of the areas of the watersheds determined to establish the sizes of all sewers. Of course, as Mr. Rice intimates, it will not do away with a large amount of engineering work of a survey nature, such as the determination of property lines, etc., but it will do away with a great deal of what we term preliminary surveys, so that engineers, after a study of the maps, can devote their attention to the details of the location of any proposed enterprise without being obliged to spend a lot of time and money in developing the feasibility of the project.

From my own experience in municipal work I feel that one of the chief values of the triangulation survey will be the possibility of establishing absolute co-ordinates for the intersection and angle points on our streets, so that the absolute location of the streets when once fixed can be accurately re-established at any time. Even though the points on our streets are accurately monumented, it is very difficult to preserve such monuments, and when disturbed it is extremely difficult to relocate with any degree of accuracy, unless there is such a definite control system to tie in the location. This survey should save a great amount of money and trouble and many lawsuits by having all surveys co-ordinated so that they can be redetermined and re-established on the ground with a minimum margin of error.

W. E. FOHL: I do not recall whether you fixed the probable time of completion of the work.

U. N. ARTHUR: That depends entirely on the amount of appropriations received. Up until the present time the work has been pushed about as rapidly as was proper. We have now reached the mapping stage and the work can be carried on as rapidly as the funds will permit, provided the necessary number of skilled men in this particular branch of the work can be secured. There are about eighty sheets within the present city limits remaining to be mapped. If ten to twelve parties could be placed in the field it would be possible to complete this work in about one year.

W. E. FOHL: In what way will these results be available to engineers and the public at large?

U. N. ARTHUR: The map sheets are to be published and will be available for distribution. We also plan to publish all information relative to the triangulation, traverse, and level nets. The sheets will show the location and number of the bench-marks and location of the triangulation monuments.

WINTERS HAYDOCK:* In addition to those you have mentioned there are a large number of private land owners who would use the surveys in developing their holdings, are there not?

U. N. ARTHUR: Such property owners should find the topographic maps very helpful in the development of their properties, and especially in the subdivision of the larger tracts.

J. M. RICE: In order to make this available earlier, does the program contemplate picking out undeveloped areas for the first mapping, like the Frick Woods, or the section between Stanton Avenue and the river, or the undeveloped section north of Beechview, which are only partially laid out at the present time?

U. N. ARTHUR: It is our intention to map such areas first. We started mapping at the eastern city line and have the field work com-

*Chief Engineer, Transit Commission, Pittsburgh.

pleted for the entire area within Frick Park. In one of the larger areas you speak of, in the Beechview and West Liberty districts, the traverse is now practically completed. We expect to follow as rapidly as possible with the mapping of former St. Clair Borough and certain outlying districts on the North Side.

J. M. Rice: Those places that are likely to need it first would save a lot of money by the survey to that extent.

U. N. Arthur: Yes. For instance, we have mapped the sheet covering the location of the proposed bridge across East Street from Perrysville Avenue to Reserve Township and the Spring Hill district. We are trying to anticipate future improvements and developments such as that, and get the districts mapped in advance as far as possible.

J. M. Rice: In order to tie that into the old monuments will you have to rerun them with the same accuracy of your traverse system?

U. N. Arthur: Yes, we will have to run precise traverse to include all monuments.

J. M. Rice: That is quite a job.

U. N. Arthur: We realize it is a very troublesome job.

Webster Hinnau:* Mr. Arthur deserves to be congratulated and commended for offering such a comprehensive paper upon a subject of which so little is known. It certainly should be gratifying news to the average engineer in the Pittsburgh district to know that a survey of this kind is being undertaken and at last the city and county have an accurate geodetic and topographic survey well under way.

The necessity for such a survey to be followed by complete maps has always been very apparent to the local engineers, and its need is very clearly shown when we know it is next to impossible with our present information to try to determine the true direction or bearing for the most of our streets in this city. This lack of information often

*Manager and Civil Engineer, McCully Engineering Co., Pittsburgh.

makes it impossible to place upon a plan of survey the necessary data often required to draw a correct description of a piece of property which may be in transfer. This predicament is often very embarrassing to an engineer, as the average client knows very little of such matters, and the less he knows the more difficult it is to explain such inaccuracy. After this survey is completed our worries over the variation of the compass and the declination of the needle should be at an end, and there should no longer be any excuse for deeds of adjoining properties giving different courses or bearings for the same common line.

If the members of council could realize as we do the importance of this work, they would gladly appropriate enough money to push this survey to completion as quickly as possible. On the basis of the figures quoted, giving the cost of this work as averaging $1.50 an acre, there certainly could not be any complaint as to cost, for I know the average engineer, including myself, can not take topography for much less than $15 an acre.

When Pittsburgh and Allegheny County have this survey and map completed and the co-ordinates of all monuments of various street corners, it should then be followed by a state act and a city ordinance requiring all descriptions and surveys to be made and drawn in accordance with this geodetic survey, and half the trials and tribulations of the various engineers and surveyors would be at an end.

MORRIS KNOWLES:* Since his earliest connection with the city and civic affairs, the writer has been vitally interested in the subject of an accurate survey for the city of Pittsburgh. His attention was first directed to the seriousness of the situation in connection with the studies and preliminary surveys for a proposed new water-supply for Pittsburgh. This was in 1897 and 1898. The paucity of data with regard to the outlying limits of the city, where new works were to be located, was early made clear.

The next notable evidence occurred during the period from 1908 to 1910, in connection with the work of the Pittsburgh Flood Commission and service upon the Engineering Committee thereof. The studies for protection of the city made it apparent that accurate maps of the city and the river fronts did not exist. At this time some local

*Chairman, City Planning Commission, Pittsburgh.

surveying was done for the particular areas to be studied and the triangulation system of the river survey was tied in with some of the city data and railroad surveys.

About the same time, in 1910 to be exact, the Civic Commission called attention to the need of such data in its work. This body was headed by H. D. W. English, who had not only conceived this activity but the Flood Commission work as well while President of the Chamber of Commerce, and was actively interested in both. He requested a few friends to serve on what was called the "Pittsburgh Civic Commission" to study the physical needs of the city. The writer is pleased to have been among the number.

The Sub-Committee on City Planning employed Frederick Law Olmsted to make a study of the main thoroughfares and to report as to desirable improvements. Here again the lack of accurate map data was at once apparent. Some of the comments in this report are particularly pertinent, as for instance:

"No other city has such imperative need of accurate and comprehensive surveys as a basis for the layout of streets, sewers and all public works, for the purpose of avoiding the extravagant mistakes, misfits and reconstructions that are bound to result from groping, piecemeal work done amidst such obstacles.

It is not necessary to give a long list of examples of incompleteness and inaccuracy of much of the old data . . . Every surveyor and engineer in Pittsburgh . . . is familiar with the conditions . . . That there is no adequate system for protecting the monuments that do exist, so that the city has no sure recourse against abutting owners who have encroached upon a street; and finally that no general official surveys whatever exist of the complicated topography of the undeveloped areas."

Following this, it was recommended in this report that:

"Pittsburgh should take example . . . because its peculiar topography is bound to make evil results of unprogressive medieval methods more serious than in other cities. It should take pains to *surpass* rather than to lag far behind in this respect."

The objects then stated to be attained were:

"A.—an accurate framework of reference points;

B.—the existing local surveys and records to be tied into the framework thus established;

C.—complete topographical maps based upon the framework first described."

The writer's next experience was in 1919, when the newly formed Citizens Committee on City Plan faced the ever-recurring problem of making studies for the development of the city and its environs. Again, the scarcity of map data of an accurate nature was early evident. It was also apparent that dissipation of much money in surveying alone would be discouraging to an active business mind that likes to see results. For this reason a program was developed to make a map of the city on a 400-foot scale and another map of the county, including the city, on a 2000-foot scale, which should be reasonably accurate for general planning purposes.

It appeared feasible to co-ordinate some of the important work done in the past and thus prepare the framework of such a map, upon which were to be placed the details, the latter to be acquired from various public and private sources. This work was carried on during the 12 months ending in the summer of 1920, with a force of 50 men, and it is gratifying to know that a really creditable piece of work was accomplished, at a small expense.

The method followed was to secure the original data of the various earlier triangulation and traverse surveys, making new observations and measurements where necessary, to tie in with one another. The whole network was then recalculated to a common basis, checking up traverse closures and reducing various level bases to a common system, so that the data acquired from various engineers and municipalities could be plotted on a uniform basis. From these, and the utilization of all the municipal, railroad, public-utility and private maps of the district, assembled and studied, we were able to prepare these maps for the county and city areas. These served as an excellent framework for all of the planning work of the Citizens Committee which has become so familiar to the citizens of Pittsburgh.

With this historical background and with the realization of the need of accurate survey data, the writer was quite ready, upon his appointment to the City Planning Commission in 1922, to discuss anew the important question of the basic survey for the city of Pittsburgh. It was realized that much preliminary planning could be done with the existing maps; also, that detail planning would require special survey information for the area to be studied. Nevertheless, for the purpose of having an accurate framework, not only for the city but for the entire county; for the purpose of establishing all relations,

horizontally and vertically, upon a common basis; for the purpose of fixing points on which all engineers and surveyors in the district could base their work; for the purpose of giving an opportunity to the city authorities to indicate the reasonable lot and block development of certain parts of the unbuilt acreage; and for other reasons, too obvious to be mentioned among engineers, it was early decided that one of the important functions of the City Planning Commission would be to try to provide for such an accurate survey.

It is gratifying to note that upon such recommendation, and with the approval and warm support of the Mayor, city council was good enough to appropriate $25,000 for the year 1923 to begin such a survey. The next year $50,000 was asked for. The sum of $25,000 was first appropriated and an additional amount of $15,000 was made available before the end of the year. In the year 1925, with a similar request, only one-half the money was appropriated. But during this year arrangements were made with the Commissioners of Allegheny County for the use of $25,000 to expend upon extending the triangulation and precise traverse survey into the territory of the county outside the city limits. At such rates of appropriation it will take a total of 10 years to finish the work for the city area.

When one realizes the importance of this work and when a few samples of finished maps are shown, it is hoped that engineers, realtors, and all having vital interest in such map records will see to it that more liberal appropriations of money are made available for carrying on the work. Such work is really a capital expenditure, because it relates to records to be used for all time. It furnishes data to be used in various expenditures for public works which are outlays of capital. For this reason such moneys may very properly be raised by issuance of bonds rather than by dependence upon annual tax levy and appropriation from the budget.

The survey itself has been so carefully and completely described by the authors that little remains to be said about the methods employed. It should, however, be of great interest to the engineers to have these data recorded in so complete a manner. It is gratifying to knew of the general approval accorded to the work, now that its character and purpose are fully realized. Perhaps this is not only the most complete record published in engineering proceedings of such surveying and mapping, but Pittsburghers may take pride in the fact

that, in harmony with the recommendations in the report of the Pittsburgh Civic Commission by Frederick Law Olmsted, the city has taken pains to *surpass* rather than lag behind in the character and quality of this work. The accuracy, while not meticulous, is the best that has yet been planned for such a survey. It continues to be carried out with the care that was contemplated and promises Pittsburgh a valuable contribution to the ultimate betterment of the city.

STEEL-PLANT OPERATING COSTS FROM AN ENGINEERING POINT OF VIEW*

By L. C. Edgar†

INTRODUCTION

In the minds of most people to-day there is a better understanding of the economic fundamentals of good business than ever before in the history of this country. Some of the theories and practices advanced a few years ago would receive scant consideration to-day. The basic principles underlying prosperity and depression are better understood, and more conscientious effort is being made to carry out right principles than was made a few years ago.

The scale or standard of living conditions of a nation is determined by the productive capacity of the people of that nation. We, as a nation, demand a very high standard of living as compared with other peoples, and therefore our productive capacity must of necessity be high. In the last decade we have added to our lives many things that have increased the comfort and convenience of living, and the luxuries of yesterday are the necessities of to-day. We have absorbed into our national life the automobile, which has added largely to our enjoyment of life and to some extent to the productive capacity of the nation. We have added good roads which, like the automobile, have added greatly to our pleasure and have increased our productive capacity. The growth of electric power has multiplied our productive capacity and has gone a long way towards making possible the producing of many other things for our comfort and convenience. We have added household conveniences which have enabled many housewives to do their own work, thereby releasing many pairs of hands needed for other work in our complicated life of to-day. The radio, telephone, and countless other things make for our pleasure and convenience.

However, all of these things put an increasing demand on our productive capacity and make the need of greater and more economical production not only desirable but absolutely necessary for the scheme of living. This productive capacity can not be increased or carried

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on more economically if waste prevail where thrift and economy should be. The President of the United States, Judge Gary of the United States Steel Corporation, and many other government officials and business men, are talking and working to-day to put this principle before the business men and people of the United States. Not only capital, but labor, is realizing the importance of this principle. In a current magazine there is an article by William Green, president of the American Federation of Labor, in which he brings out the fact that if the high standard of modern living is to continue for American labor it must help fight waste. This is contrary to the ideas of labor in the past, when it held the theory that "the more waste, the more work there would be," which is one of the worst business fallacies that ever existed.

Our country is new, and we must of necessity do a great deal of construction and development work in order that a high standard of living may continue. This requires labor, and we must do the work economically. It is obvious that we are not a nation of supermen, and we must therefore use our brains to devise ways and means of producing more and more by the use of machinery and power. It is fitting that we as engineers consider this very important subject, so close to the welfare of the business of the country, and to which the work of the engineer is so closely allied. It is primarily the objective of the engineer to produce as much as possible with minimum possible use of work, men, materials, and power. This is particularly true of the steel-works engineer, and is increasingly important in view of the fact that steel is being used more and more in producing the things which we need in every-day life, and in the construction and development work necessary for the future.

We sometimes go astray in our engineering in attempting to make impressive and intricate machinery for our glorification, and not for the accomplishing of the ultimate object, which is the producing of as much as possible so as to get out product with the lowest possible cost in men, materials, and power.

It is the primary object of this paper to cover in a general way a few of the fundamental principles governing engineering in its relation to the production of iron and steel of good quality at a low cost. There are, of course, many specialized lines of endeavor concerning which an evening could readily be spent, but it is not the intention of

this paper to give specific technical details. The purpose is, rather, to cover in a general way certain principles that should govern the engineer in his work; certain methods of procedure which I hope may be of some benefit, especially to the younger men present.

The first thing to which I wish to draw attention is the necessity for the engineering department of a plant to have a comprehensive plan for the improvements and changes contemplated, in order that satisfactory results may be accomplished from an engineering point of view as well as from that of operating. No business or project can hope to be successful without working toward some ideal or plan. The comprehensive plan will no doubt be crude when first drawn, and lacking in vision and detail, but as the years go by it will be found to be increasingly useful as a guide to the work being done, not alone for large but also for small projects. There are often installed in plants things which, with the aid of a comprehensive plan, could be made differently so as to fit into the ultimate plan much better.

The first need in working out a comprehensive plan is a knowledge of existing facilities. Without such knowledge, the forecasting of proposed improvements is, of course, impossible. The engineer must be sure that he knows the existing facilities and conditions as well as he should. There is a tendency to skip over what might be considered minor points that eventually add to the cost of operation. The engineer should have a knowledge of existing costs. By this I mean a detailed knowledge of what contributes to cost. He should be familiar with possible ways and means of eliminating the things that contribute to high cost of operation. There must be a knowledge of interdepartmental capacities—a knowledge of the scheduled relations of the departments and their ability to adapt themselves to scheduled demands. A study should be made in regard to the existence of any weaknesses which may interfere with maximum production. In the train of operations from the blast-furnace to the finished product it is possible there is only one department which interferes with a considerable increase of plant production. I know of a condition where the capacity of the soaking-pits interfered with the production of the open-hearth furnaces; not that the pits did not have sufficient heating capacity to produce the tonnage for the other department, but the lack of synchronism between the departments made more reservoir capacity necessary. Adjustment of this condition resulted in increasing the

productive capacity of both the open-hearth and the mills. This is just an example of the many things that might interfere with production.

It should be borne in mind that production is of paramount importance when considering costs. The blast-furnace, the open-hearth furnace, and the mill operate on approximately the same cost per day whether the tonnage be a maximum or a minimum.

It is not always possible for the engineer to know the future requirements of his plant, but he should make it his business to ascertain as far as possible what they are, and study the matter so that if the future does bring a suggestion of any facility that the plant does not have, he will be able to give intelligent counsel on the subject. If he does know of possible future requirements, an intensive study should be made and the results should be embodied in the comprehensive plan.

A general knowledge of the various features included in the work of an engineer should be acquired not only by the engineer, but he should give employees of the engineering department opportunity, by reading and observation, to keep posted on current improvements of related business such as electric light and power, steam, water-works, and many other things connected with engineering in steel-works. The men of the department should have plenty of literature available and should have opportunities for study. The worst kind of economy is economy in books and magazines.

There will be changes from year to year in a comprehensive plan. It should be revised each year to meet changes in operation and to keep in line with progress in the various lines of business involved. In order to have a good comprehensive plan it is necessary for the engineering department to have a thorough knowledge of the organization and forces of the plant and to know especially of such organizations and forces as overlap. In connection with the installation of new facilities it is often possible to consolidate organizations and forces, thereby reducing the number of men required to carry on a certain work.

It goes without saying that a comprehensive plan requires vision and the digging up of facts regarding facilities, costs, and organization in order that it may be of value for the present and the future. Accurate records are an important tool of the engineer in his develop-

ment of new facilities and in his study for the betterment of existing facilities. They are of primary importance if low cost is to be obtained. The records must be accurate, simple, and understandable. For cost examination purposes the number of men or quantity of labor is better than a monetary cost on account of the greater ease of visualization of the changes necessary to accomplish a reduction. The record should be available promptly and continuously in order that the operator may not have to wait, but can remedy excessive expenditure as soon as it appears. Sometimes costs are simply relative distribution, and actual saving can not be had by a change. There are many other things in connection with cost which may appear somewhat indirect to the engineer who has not made a study of the subject. It is the duty of every engineer who has anything to do with comprehensive planning or designing of facilities to have a very thorough understanding of the accounting methods of his plant if he expects to give accurate advice in connection with possible savings in cost.

Co-operation and competent counsel are important in the duties of a steel-works engineer. There should be consultation with the heads of departments in connection with a comprehensive plan. The department heads should write out and give to the engineer their ideas of their own departments. These ideas should be gone over by the engineer and threshed out in connection with the comprehensive plan of the plant, and their relative merits carefully weighed, the more important items being given preference. The suggestions should be talked over frequently and the advantages or disadvantages discussed.

In connection with improvements being carried on, it is my belief that the heads of departments and their assistants should have the freedom of the drawing-room. In fact, they should be requested to come to the drawing-room and look over all work as it progresses. There are many refinements and improvements in connection with the engineering with which the operating man is more familiar than is the man on the drawing-board. The suggestions of the operating man are valuable and in most cases have a tendency to reduce cost, sometimes even by relatively insignificant changes. A chute here, a convenient stairway there, may make possible one less man in connection with an operation. In my opinion, the engineer who is not big enough to take this kind of suggestion is not carrying out his full duty

in the development of facilities that will secure the best and cheapest operation for his plant. It is often an advantage to secure advice from the men who are in intimate contact with the work. The suggestion should be made to the department head that his man or men should be allowed to look over the work and talk it over either in the field or in the drawing-room. In other words, the engineer should be big enough to give advice and to take advice.

When making field investigations or researches in costs, in fuel savings, or in other lines which may come under the jurisdiction of the engineering department, it is good practice to allow the superintendent of the department free access to the data; misinformation may often be avoided by a suggestion from the superintendent. In fact, co-operation should be had in all the different phases of work relating to engineering and operating. When an engineer finds it impossible to agree with the operator, a full and complete explanation of the reasons for the difference is due the operator.

STANDARDS

Standards are always of advantage in connection with the design and construction of facilities. I know it is difficult in steel-works to have as many standards with as much duplication of machinery and equipment as is possible in many industries, but I believe an interchange of details between mills, furnaces, etc., is of the utmost importance. This has a tendency to reduce inventories, which are, of course, an item of cost. Some engineers I know of do not consider an inventory as an item of cost, but in the long run it is merely interest on a certain amount of inactive money which minimizing of duplication has a tendency to reduce. In connection with the planning of new improvements it is an advantage to the operating department, as well as an aid in determining where lower costs can be made, to standardize the force; that is, certain forces should be set aside to do certain work and no men outside of the standard force should be employed. This is somewhat hard to accomplish, but I believe most operating men will agree that if you have a standard force and do not have week-end work and miscellaneous jobs which have to be done at odd and irregular times, you have a better chance of having a low cost. It is therefore the engineer's duty to make possible the performance of all work, in so far as he can, during the operation of the furnace or

mill. This means that many jobs which might otherwise be week-end or odd-time jobs can be arranged under a definite schedule, and a certain group of men can go from one job to another in regular sequence, thereby forming a standard force to carry out irregular work. Then, in case the mill is down, all of the force is off, which results in more satisfactory cost than can be obtained by any other method. Standard practices and methods should be developed where possible, and it is the engineer's duty, when designing, to consider the item so as not to handicap the operator in establishing standard practice or methods.

The orderly method of doing things, or, as it may be termed, discipline in an organization, reflects itself in the cost sheet and in the safety work of a plant. In designing work the engineer should be careful that nothing is installed which interferes with orderly procedure. The orderly arrangement of equipment, spares, etc.; an orderly system of handling materials to and from the departments; suitable and convenient places for the storing of supplies; and proper means for cleaning up and providing of places for disposal of material, are all essential if the operator is to have a well disciplined plant. As orderliness is reflected all along the line, it is an item of importance which I believe the engineer should consider in connection with designing.

To illustrate some of the developments that have been made to reduce cost, I will briefly run over a few things in connection with various departments of a steel plant, taking the blast-furnace first.

BLAST-FURNACE

The output of a blast-furnace is most important. The cost per day of operating a furnace, from a purely labor standpoint, differs very little whether the furnace production be 500 or 750 tons. Therefore, from a labor standpoint the 250 tons are "velvet" to a large extent.

The development of our blast-furnace lines is rapidly increasing the possible tonnage of the furnace, and every furnace man and every engineer connected with blast-furnaces should make a thorough study of lines with the idea of increasing the tonnage of the plant. Furnace lines, of course, have an influence on the product and also an influence on cost. If a furnace does not have the proper lines, the result is

irregular working, scaffolding, high flue-dust production, and all the difficulties so familiar to blast-furnace men. These conditions result in a high coke rate (which requires the blowing of high wind) and curtailed production, both of which contribute to high cost of operation.

There have been many improvements in the last few years in stocking and charging, with consequent reduction in the number of men employed. In fact, a paper was recently read before a certain society about a "one-man furnace," where the larry-car operator not only brought materials from the bunkers to the furnace, but operated the blast on the furnace. This was made possible by development of larry cars, door-opening devices, etc. In connection with handling of ore and stock, there are certain items of importance which the engineer can consider. First of all, there is the track system and the bringing in of material. Every plant has this problem in a greater or less degree, and it is difficult or easy as the site adapts itself to the work. At the Edgar Thomson plant of the Carnegie Steel Company, we greatly reduced the cost by removing the lump grids over the bunkers to the car dumper. This was a simple thing and the lumps were broken much more easily at the car dumper. The gains from the change were out of all proportion to the expenditure.

In recent years increasing attention has been paid to proper distribution. Some of the methods of securing distribution a few years ago, when furnaces were smaller, are impossible of satisfactory operation to-day on account of the character of the ores used and the size of the furnaces. There are tops on the market to-day which add materially to the satisfactory operation of the furnace.

There are many other things that could be done along such lines, and a careful study by an engineer will reveal them.

In connection with the blowing of blast-furnaces, the trend of most furnace men is toward turbo-blowers. This is logical and in most cases reduces cost. Fewer units are needed and more accurate measurement of blast is possible, with greater regularity and better knowledge of furnace operations, all of which tends to cost reduction. In many cases the blowers are equipped with jet-condensers, but in two cases I know of they are installing surface-condensers, which are to be in series with the plant water-supply and should have a tendency to reduce the cost of water for condensing purposes and for blast-

furnace operations. The supplies and operating labor for turbo-blowers are lower than for other units and they permit the centralization of blowing houses, which is impossible with the cylinder-type machines on account of the necessity for short lines between cylinder engines and furnaces so as to avoid what would in many cases result in disastrous fires. These things, coupled with first cost and maintenance, have led furnace operators to the consideration of turbo-blowers.

The casting at a blast-furnace can be reduced by the use of short runners, both for iron and cinder, and the utilizing of improved designs of mud guns and cinder stoppers. While the savings are not enormous, small economies are an important factor in reduction of steel-plant costs.

MISCELLANEOUS LABOR

By studying cost sheets, an engineering department can do many things in connection with miscellaneous labor, possible needs for improvement in flue-dust handling, general clean-up facilities, disposal of scrap, handling of materials such as sand and clay, and the work in general of miscellaneous labor gangs doing odd jobs throughout the plant.

WATER AND STEAM

Conservation of water and steam is important. Leakage in steam lines and traps should be studied. In many cases the simplest of facilities is the best. The use of plates in series to save water is a small item on a blast-furnace, but results in low cost. These things were not used in many plants until a few years ago. Bad valves, and many lines where only a few lines are necessary, increase cost on account of leaks and other losses.

All of these items should be considered in connection with a comprehensive plan, and no doubt important improvements will occur if they are carefully studied.

OPEN-HEARTH FURNACE

The open-hearth furnace is like the blast-furnace in that production is most important. The ideal method of operating an open-hearth furnace is, of course, to operate it continuously, thereby eliminating the loss of heat which comes at shut-down periods. Regardless of the design of furnace and checkers, there is considerable leakage and other

difficulties incident to maintaining furnace temperature during shut-down periods. The probabilities are that when a furnace is started up after a shut-down it will take several heats before the furnace is in as satisfactory condition as it was before the shut-down. As it is impossible in most plants to operate straight through, the next best thing is to pay particular attention to keeping the furnace warm during the shut-down period. Here is one place where sealing a furnace tight is especially important, as air infiltration and leakage have a serious effect on the furnace temperature. In connection with the operation of furnaces continuously, there is a practice in some plants of holding heats to meet mill conditions or the holding of charging back to meet mill conditions or schedules, which, of course, is detrimental to furnace operation. The principal thing the engineer can do in connection with the matter is to design his furnace and reversing mechanism and everything connected with the furnace with a view to keeping the furnace tight. In reversing mechanisms, proper sequence of reversals is important so that there be no blow back to open up crevices or cracks in the setting.

Constancy in the calorific value of producer gas, where such fuel is used, is of primary importance. Irregularity makes operations difficult, as it requires changes in setting from time to time, and these are not always made during the melting period, and consequent inefficiency of operation results. In order to get good production on the producers, and good gas—both of which are essential—and in order that the operation of the producers may be carried on at as low cost as possible, I believe in standard practice operation—that is, operating a house on certain definite standards, such as standard steam pressure, standard fuel levels, standard cleaning time, etc., deviating from the standards only with the consent of the foreman. The practice of operating producers on the individual notions or ideas of the operator has proved to be wrong at the Edgar Thomson plant, where a marked improvement in the gas production and the tonnage of steel produced per pound of coal were noted with standard practice operation.

The furnace, particularly the checkers and flues, should be kept tight if good combustion is to result, and if efficient operation of the furnace is to be obtained. Careless arrangement of openings and the installation of devices that are not convenient are detrimental to the

good operation of an open-hearth furnace. Designers should provide for keeping checkers tight, and keeping valves covered, so that no leakage or infiltration can occur. Some of the designers are figuring to-day that a steel jacket is an advantage on checker chambers, and I am inclined to agree.

A great deal of work is being done on design of furnace ports. Of course there are many different kinds of ports and there are different fuels, but I think it is well worth the engineer's study to develop a proper port design for the particular fuel used in the plant. Some plants are experimenting with automatic control of combustion. Forced air and gas is another ramification of the effort to get good combustion.

All of these things are in the interest of large production and with it, of course, comes lower cost.

The open-hearth furnace is too detailed a subject to consider at this time, but any engineer having to do with an open-hearth plant had better keep his ear to the ground, as open-hearth practice is progressing rapidly.

Stocking and charging are primarily matters of lay-out, if low cost is to be secured. A good lay-out should provide means for prompt delivery of material from the stock house to the furnace, with as little interference as possible with the operations of ladle cranes and charging machines. In many plants the roller-bearing car for charging and the roller-bearing mold car are producing lower cost, not only in locomotives, but in cost of operation of the cars, as repairs on roller-bearing cars are less than on those with plain bearings. The handling of materials in the open-hearth furnaces, as in the blast-furnace, is a large item of cost, and any engineer would do well to consider it. The clean-up handling provision is often overlooked and results in much hand labor. The wheelbarrow has been a favorite conveyance. Cinders, scrap, and other waste material should be taken care of efficiently.

ROLLING-MILLS

There are so many different conditions in the mills that specific analysis at this time is impossible. However, I will mention a few things which should be of advantage.

Production is most important, as in other parts of the plant. Consideration should be given to duplication of parts, bearings,

motors, and arrangements for facilitating quick repairs on the shut-down of a mill. The cost piles up every hour the mill is shut down. The day-by-day operation of the mill is not very different whether the tonnage be large or small. It is therefore important that tonnage be kept up to the maximum.

The handling of waste and supply material in connection with the mill is most important. The handling of scale, of bearings, of oils and lubricants, and the general clean-up work should be carried on during operating times so as not to interfere with productive labor. As many things as possible should be handled by gangs delegated to do miscellaneous work, so as not to make it necessary to have week-end labor. Standard forces should be established so that a study of these forces will reveal the high points of cost, and remedies should then be provided.

The handling of labor in repairs in all departments is the bugbear of the operator who is trying for low cost. I am in favor of the budget system for the handling of repair items, to be based on mill operation. The operation of a budget system could be carried on about as follows. Basing it on the operating time of the department considered, a perusal of the records would reveal the amount of labor being used from time to time in the maintenance of that department. A comparison of the cost sheets of various competing plants would reveal the relation of the costs to other plants. A study of the high and low months would reveal the limits within which the budget should be confined. After such a study, and in consultation with the operating and mechanical departments, a maximum allowance of men-hours for different operating percentages could be arrived at. It should be understood that in no case are the repairs to exceed the budget unless by mutual agreement between operating and repair departments and, if thought desirable, the approval of executives higher up should be necessary. Then, if it were necessary to do a large job in one month, the mechanical department would curtail items of expense which could be put off until later and would not lump two or more large items in a month which would make the cost go up and down and be very irregular. The whole tendency would be for the mechanical department to conserve its labor and repairs so that there would be satisfactory leeway for large jobs, and attempts would be made to reduce the budget in order to make a satisfactory showing.

The budget assures the operator that large items of repairs can not be undertaken without full consideration. It draws attention to the weak points of cost, for the benefit of the operating and engineering departments, and this attention should be followed by consideration of, and the devising of ways and means for, reducing the cost. It has a stimulating effect on the mechanical department, as it establishes a standard for operation. The mill has a standard of operation, as it produces a certain tonnage at a certain cost, and the millman has a standard force which he endeavors to maintain, but in many plants the mechanical department works by hit-or-miss methods. In some cases it does things that are not necessary, as the shop men must be kept busy and can not be laid off. With a budget, however, the mechanical department has a standard by which to determine whether it is doing good work, and, if it is able from month to month or year to year to reduce the budget by adding little items of improvement, it is a mark of good work and should be commended and due credit given. If, on the other hand, the mechanical department does not carry out the provisions of the budget, then it is subject to censure.

The handling of material throughout a steel-works is important. Ways of getting to equipment by road or truck should be considered by the engineer in his design work. There should be an established, scheduled delivery service for small items, such as supplies, oils, and other commodities ordered either by telephone or letter. This results in the saving of men in the handling of supplies and is more satisfactory to a department after it becomes accustomed to the system.

Too much stress can not be laid on miscellaneous items which are not ordinarily considered by the engineering department. In the main, the items that contribute to the highest cost in the steel-works are not those of producing and operating labor, although sometimes they are. Generally the cost is made up of many items which are not ordinarily considered as being dependent on engineering. In many cases the operator is conscientiously endeavoring to keep down the miscellaneous costs. In arranging designs, providing locations for facilities, providing for transportation, and in many other items, if thought and care are not taken in the location and installation, the engineer can make impossible the economy that should prevail. Often a relatively small facility, such as a storage house for oxygen, might be apparently located in a satisfactory site, but the location might require

unusual or difficult transportation arrangements. There are many such facilities that are often not given a proper location and concerning which there is not a free and frank discussion with the operating departments as to their needs, or an earnest attempt made to provide facilities that can be operated with a minimum of labor. In designing track systems, simplicity should be the watchword. The avoidance of crossings is important. If you check up the cost of your crossings you will be surprised. We were. There is no place for the installation of new crossings in our plant, but almost any other arrangement of tracks is acceptable.

A discussion of fuel conservation in a steel-works might fill a book. However, I will touch on a few of the high spots, as fuel is a large item of cost. In coke, the saving is of course arrived at by improved furnace lines and enlargement and improvement of stoves. The saving in blast-furnace gas in the past few years has been remarkable. They are burning gas to much better advantage at the stoves. Automatic control systems which give extraordinary results are in operation. Checking of the combustion, by Orsat apparatus or other means, is of considerable advantage and results in large fuel saving where more modern facilities are not available.

The saving of blast-furnace gas on boilers is going forward rapidly, by the installation of better boilers, better burners, with automatic control and regulation of combustion. If modern burners can not be installed, a man with an Orsat apparatus can save his salary many times over by teaching the fireman, and in many cases the boiler superintendent, what a real blast-furnace-gas fire looks like.

In the open-hearth furnace, fuel is being saved by better design of furnace and checkers, making possible a tighter furnace with less infiltration of air; and by better damper regulation. At the present time, an experiment is being conducted on automatic regulation of the open-hearth furnace with certain fuels, which is a step in the right direction. If this regulation can be worked out, it will relieve us of many causes which contribute to lack of production, such as poor damper regulation and poor combustion. Better port design is improving combustion, in many cases, getting the heat into the bath where it belongs. The waste-heat boiler is taking waste heat out of the stack and putting it into the steam line. There are many other

things being considered and attempted at present in the effort to save fuel and increase production.

There is probably less chance of fuel conservation in the mills than in the blast-furnace or open-hearth furnace. Nevertheless, automatic control of heating furnaces is being tried with extraordinarily good results, and it is found in many cases that by replacing manual control the production is increased and a more even heat is secured with less fuel.

The application of powdered fuel, oil, tar, and coke-oven gas, all present problems of their own so far as fuel conservation in a heating furnace is concerned. It is out of place in this paper to discuss in detail any of the various phases of this subject, except to say that it is the duty of every engineer to keep abreast of the times as regards any fuel he may have to use. The various companies handling combustion apparatus are ready and willing to assist in the solution of these problems. The only suggestion I have to offer is that when considering the problems, all of the available information should be secured rather than to obtain it entirely from one source.

SAFETY

I would not feel that I had covered my subject without adding a few words about safety. The steel-works of to-day is paying more attention to the safety of its employees, and there are fewer and fewer accidents in the steel industry as the years go by. There is an economic advantage to all of us in the elimination of waste, the reduction of cost, and increase of production; but there is also a great saving to us in the fact that there are fewer maimed and fewer killed in the industry to-day than in the years which have gone by. There is no doubt of this and no argument against it, and the work is being carried on by the enthusiasm of those who come in daily contact with the operations. The managements of all plants recognize the advantage of having their plants free from accidents. Year by year the men in the plants are becoming more and more interested in safety work. Safety, however, is a matter of interest, and the interest has to be kept up in order that the good work may continue. It has been my observation that a plant which stands high in safety usually stands high in other things. A plant with a poor safety record often has a poor record in other ways.

CONCLUSION

A general paper of this kind must of necessity be lacking in specific information, and it is therefore not to be expected that you will obtain from this one an exact answer to any of your problems. However if you have secured an idea or plan of procedure, or a suggestion that may help you in attacking your specific problem, I shall feel more than repaid for my effort.

DISCUSSION

A. C. Fieldner, *Chairman*:* We are indebted to Mr. Edgar for a most stimulating review of engineering progress in the iron and steel industry. He has pointed out what has been done in the past by co-ordination and has set forth reasons why this country leads the world on the engineering side of iron and steel production. There is absolutely no question about that. But to me, his paper is of special interest because there is a note that indicates that in the future the engineer will not only put into practice the best engineering knowledge he has, but he is also going to question some of that engineering knowledge by either experimental work or the substitution of better materials or better methods, saving the wages of a man here and there. We have every incentive to do that in this country with our high wages. I asked a man in Europe some years ago why they did not put in some mechanical punchers in their coke-ovens. He said, "What is the use? These men do not cost much, but the machine costs a good deal." In America we have a much greater incentive for engineering work. I am sure Mr. Edgar's paper will stimulate discussion.

J. S. Unger:† I am very glad I am able to be present this evening to listen to Mr. Edgar's very excellent paper. A few of the points in his paper might permit of further discussion.

In the building of a new mill, one of the most important points, which many engineers lose sight of, is to provide adequate shipping

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facilities. The facilities usually provided are only sufficient for shipping the mill production of a certain size of section in car-load lots over a few routes. When the mill is running to capacity and rolling many sizes, which are to be shipped over many routes, and are to be accumulated on the beds or in the yards waiting for car-load lots, the problem is an entirely different one. Very few mill designers give the latter situation the attention it demands, with the result that inadequate shipping space and facilities determine the capacity of the mill.

The author referred to sufficient soaking-pit capacity to heat the steel. When a member of open-hearth furnaces bunch their heats, I have observed that if the ordinary mill had four times the number of pits, it would still not have enough. As a consequence, the steel must be held in the open-hearth furnace until the pits can take it. The question is, when does a mill have sufficient pit capacity? To provide enough pits to take care of the peaks would not be economical on account of high fuel costs.

Another item of cost is yard switching. In the older, congested plants this is an important item. When the mill was built it had more space to handle its product and supplies. As it grew older its production increased, and the surrounding territory was covered by other mills or buildings. The switching facilities were reduced, while the costs were increased. There is hardly any item in mill costs that creates quite as much confusion, discussion and profanity as switching charges. An engineer must give this item the most careful attention in his designs. To cut it to the minimum, possible future extensions must always be considered.

The department superintendent of to-day is much more familiar with the details of his mill costs than he was 15 years ago. The costs of labor, material, and supplies have more than doubled, but the selling price has not kept pace with production cost. Competition is keener than it was formerly. This means that all items of cost must be more carefully studied and greater attention paid to every item of cost, regardless of how small it may be. There are certain costs over which the department head has no jurisdiction. I refer to such general costs as clerical or engineering charges. In case a department is operating at, say, one-third to one-half capacity, it is sometimes possible to reduce the actual operating labor to what is required for operation. The general charges are not reduced in proportion to the

production charges. As a result, costs under curtailed operations are increased.

A. C. Fieldner, *Chairman*: I have a question which I would like to put to Mr. Edgar. What is the general practice with regard to charging experimental work to operating costs? I mean how extensive must experimental work be in which the engineering department or some other department engages before it is excluded as an operating cost or any part of it included in operating costs?

H. B. Mann:* I was very much interested in the progressive note of this paper, particularly that in every subject the author mentioned he seemed to have considered, and to have had his eyes trained for, the latest developments. Unfortunately that is not as general as perhaps it should be. It seems that every industry is inclined to limit its engineering and its improvements to what is done in that particular industry, rather than to survey the field and consider what other industries are doing in the way of improvements. Mr. Edgar's attitude on that subject is along the line of getting the benefit of what is being done in other fields. The one frequent excuse of engineers is that their conditions are so peculiar that they can not consider this, that, or the other thing which may have been perfected in some other field of engineering. Perhaps something that is being done in paper-mills can not be considered in certain other mills "because their conditions are so entirely dissimilar." It always strikes me that that is an excuse, because the fundamental principles underlying all of these are the same. Mr. Edgar referred to the necessity of studying those underlying principles and applying them, and that is coming to the point where in the steel industry we can get the benefit of advances achieved in other industries.

E. B. Plapp:† One of the speakers brought up the point of by-product coke-ovens in Europe in which mechanical pushers were not used because of the cheapness of labor. From what I have read, in European plants, especially on the Continent, they have facilities for saving fuel to a much greater extent than we do, and it seems to be a relation between the relative cost of labor and fuel. Improve-

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†Mechanical Engineer, U. S. Aluminum Co., New Kensington, Pa.

ments, of course, are made to gain a saving of some kind as regards expense. I would like to hear a little discussion on what the relationship must be between the saving to be gained and the expense which must be incurred to make it worth while to go to that expense.

The speaker showed one more thing, and that is that the engineer must have some operating experience to be a good engineer. In order to make any saving in operating methods, it seems to me that an engineer must know those methods to an extent which is possible only by having some operating experience himself, and that, it seems to me, is a prerequisite for successful engineering.

L. C. EDGAR: The question of shipping facilities was raised, and that brought to my mind one thing which I did not bring out in the paper and which ought to be brought out, perhaps. That is, that in designing a mill it would seem in the interests of good operation if the first part of that mill should be built for the capacity rate required of the mill. If the first roughing has a certain capacity, the second roughing should have a little more, and the finishing still a little more, and the shipping the most of all. In other words, the mill should run away with the steel. I have had experience in some mills where there was a stand of rolls that interfered with the operation and kept it down to a certain definite speed and it was difficult to get maximum tonnage. Where you place first the point that controls your rate, you get better capacity and better overall operation than when you have the pace-maker half way down. By that method of reasoning the shipping facilities should be studied to take care of the maximum tonnage of the first step in that operation.

Dr. Unger spoke of there not being enough pits. We have had many arguments about that, and one point of view I would like to offer is that I think it is the duty of the engineer and the operator to study the open-hearth operation, and, if that is worked out and improved, it ought to have a standardizing effect on the times of furnace heats. If you could always make a heat in exactly the same time, your soaking-pit capacity would not need to be so great. That is the ideal toward which we are striving, and few of us hope to accomplish it, but we hope to be nearer than we are at the present time.

The yard switching question, of course, is active. I just touched on track facilities in steel-works. They are of primary importance. The arrangement of tracks so as to have no yard switching is ideal.

If we could build the plant in a large field where we could dispose of the product and bring in the supplies where we needed them we could arrive at that ideal. However, regardless of how complicated the switching problem is, it is worthy of study. The elimination of complications in the moving of facilities is important. We have moved and rearranged an entire shop organization with the idea of eliminating trackage and cross trackage, and the result has been very gratifying. I believe that in the last year we have eliminated about fifteen crossings. The crossings cost at least $500 a year, and it was worth while.

As to the clerical force, that is something which is almost constant whether the mill is making large tonnage or small. It takes just as much lead pencil to write down 500 tons as to write 5000 tons. Whether the mill is running full or light, it is a pretty hard thing to handle. In standardizing the forces, if the mill is down completely I see no reason why members of the clerical force should have any more consideration, if they are paid adequate wages, than the operating forces. I know clerical forces have grown up under a system whereby they are always on duty regardless of mill operation, and always paid a fixed salary, and they have not been dependent on mill operation as the other men in the mill. There may be an economic rate that has been established based on that kind of operation. If there has, it is unjust to set them aside when the mill is shut down. However, it is perfectly feasible to adjust that in a proper way. I am a great believer in budgeting these forces in accordance with mill operation. I believe it has a tendency to level out and bring about a more thorough knowledge of the forces involved.

As to the charging of experimental work, where a large experiment is involved, that should be a matter of appropriation, and, if the matter has been thoroughly gone over and is presented in a satisfactory manner, I have found very little difficulty in getting an appropriation for that kind of work. It certainly is the proper way to do it. It certainly is not proper to put all that kind of work in the operating man's cost sheet. The benefit is long in coming, and sometimes it does not come, and it is not fair to the operating man to put it in his sheet. Yet it may be of benefit to the industry, therefore the management should provide funds to carry it on as far as possible with the supervision which is always at hand in the plant.

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the William Penn Hotel, Tuesday, March 16, at 4:40 P. M., President W. E. Fohl presiding, Messrs. Hunter, Clifford, Affelder, Spellmire, Covell, Rice, Eavenson and the Secretary being present.

The minutes of the last regular meeting, held March 17, were approved without reading.

Applications for membership from the following gentlemen, having been published to the Society, pursuant to the action of the Board, were elected to membership:

MEMBERS

Adams, Frank Lester
Albrecht, Frederick C.
Bloomquist, O. A.
Brotzman, William S.
Cate, Edgar R.
Dauler, Cyrus Sylvester
Davis, Ralph Emerson
Etheridge, Harry
Fowler, William E.
Hoffman, William Guy
Kinter, Charles Willis
McCrystle, J.
McIlvried, Howard George
Nimick, Alexander
Shafer, William B.
Sipe, Charles Allen
Swanberg, Floyd Ludwig
Taggart, Ralph S.
Wallace, William W.

ASSOCIATE MEMBERS

Johnson, Edwin H.
Mayhew, Norman H.
Reed, Norman James
Trimble, John L.

ASSOCIATES

Ewald, Harry W.
Gamble, Earl Rolland

JUNIORS

Gordon, Bennett Taylor
Lahr, Robert W.
Burgess, Edgar Allan

Applications for membership were received from the following gentlemen and their names ordered published to the Society. Assignment to the various grades is as follows:

MEMBERS

Bankson, Ellis E.
Ebersole, F. Leslie
Hazeltine, H. L.
Hefft, Joseph S.
Thorne, John Mueller
Vanderpoll, J. A.
Godard, R. S.

ASSOCIATE MEMBERS

Brown, William Edward
Fulkman, John A.
Manchester, George Earle
Mansfield, Myron G.
Townsend, J. F.

ASSOCIATES

Ramsey, William Guy
Simons, Donald M.

JUNIOR

Wilson, Charles Alexander McKinley

Application for transfer to higher grade of membership was received from M. E. Haworth and, after discussion, the Secretary was requested to advise him of his transfer to the grade of Member.

The Secretary reported the death of the following members:

C. F. Freeman......Joined Nov., 1920	Died March 12, 1926
J. C. McDowell....Joined Feb., 1901	Died March 11, 1926
C. L. Wilcox.........Joined Oct., 1911	Died March 11, 1926

The report of the Secretary showing the financial condition of the Society at the close of business February 28, having been audited by the Finance Committee, was approved.

The Secretary reported in the absence of Mr. Weldin, Chairman of the House Committee, an evening attendance of 478 for the month of February.

Mr. Affelder, Chairman of the Membership Committee, reported that one meeting had been held during the month to assign applications received since the last meeting of the Board.

The meeting adjourned at 5:45 P. M.

K. F. Treschow, *Secretary.*

CIVIL SECTION

The regular bi-monthly meeting of the Civil Section of the Engineers' Society of Western Pennsylvania was held in the Blue Room, William Penn Hotel, Tuesday, March 3, at 8:05 P. M., Chairman V. R. Covell presiding, 225 members and visitors being present.

The minutes of the last meeting, held January 5, were read and approved.

A further report of the Committee on Local Aggregates for Concrete was presented by Mr. C. S. Davis, Chairman, as follows:

To the Members of the
Engineers' Society of Western Pennsylvania:

Dear Sirs:

In accordance with the resolution adopted at the annual meeting of the Civil Section on January 5, 1926, your Committee on Local Aggregates for Concrete has considered the advisability of this committee taking up further work in connection with the making of concrete.

There is need of a specification for the designing and making of concrete that will make use of much of the data developed in experimental work during the last few years. Your committee believes that much improvement in the manufacture of concrete can be accomplished providing this Society can agree upon some definite directions for designing and making concrete.

We, therefore, recommend that a committee, representing all branches of the industry, be appointed to draft a specification for designing and making concrete.

This committee, during its studies in preparing the recent specifications, found that there was a lack of information concerning the effect of certain variables on the properties of concrete and that further investigation was needed in order to solve these problems. Among those that require additional study are the following:

1. Soundness tests of Pittsburgh gravels, slag and stone.
2. Interpretation of the colorimetric test with reference to Pittsburgh sands.
3. Permissible limits of coal in Pittsburgh sands and gravels.
4. The economical use of crushed sand in Pittsburgh.
5. Permissible limits of flat pieces of gravel.
6. Application of the Abrams' theory of proportioning to Pittsburgh aggregates.

The solution of these problems will greatly aid the committee in its work during this coming year.

While the committee realizes that the Portland Cement Association in its Structural Material Research Laboratory at Chicago carries on very extensive researches in concrete, we believe that the problems mentioned above are largely local and that the Association should not be expected to study strictly local problems.

This committee desires to recommend that a fellowship be established for the year 1926-27 at the Carnegie Institute of Technology, to be filled by a properly qualified young man who will make a study of any or all of these problems. This fellowship might be on a half-time basis or on a full-time basis. If on a half-time basis, the holder of the fellowship might also qualify for the degree of Master of Science in Civil Engineering during the year.

The committee further recommends that this fellowship be financed by the aggregate producers, cement companies, contractors and others in the district who are interested or who would profit by the results of the investigation. The amount required would vary from about $750 to $1,400, depending upon whether the holder of the fellowship was on a half-time or full-time basis. The Institute will furnish, without charge, its laboratories and laboratory equipment.

Respectfully submitted,

C. S. Davis, *Chairman;*
F. M. McCullough,
A. C. Toner,
P. J. Freeman,
Committee on Local Aggregates for Concrete.

On motion, duly seconded and carried, Mr. Danforth recommended that the matter of fellowship be referred to the Board of Direction for their consideration and action.

As to the remainder of the report, it was moved and carried unanimously that the present committee be continued to pursue that investigation. It being suggested that the recommendation of the committee is that such committee should be large enough and representative of the industry, the original motion was amended to read that the present committee be continued and enlarged as indicated in its recommendation, and the motion as thus amended was carried.

No further business coming before the Section, the paper of the evening, on the "Delaware River Bridge," was presented by Clement E. Chase, Principal Assistant Engineer, Delaware River Bridge Joint Commission, Philadelphia, Pa.

On motion, duly seconded and carried, a vote of thanks was extended to Mr. Chase for his interesting address.

The meeting adjourned at 10 P. M.

K. F. Treschow, *Secretary.*

REGULAR MONTHLY MEETING

The four hundred and thirty-seventh regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Ball Room, William Penn Hotel, Tuesday, March 16, at 8:15 P. M., President William E. Fohl presiding, 62 members and visitors being present.

The minutes of the last meeting, held February 16, were read and approved.

The Board of Direction reported the election of nineteen applicants to the grade of Member; four to the grade of Associate Member; two to the

grade of Associate; three to the grade of Junior; and the receipt of fourteen applications for membership. One member was transferred to higher grade; three resignations were accepted, and the death of three members reported.

No further business coming before the Society, the paper of the evening, on "The Liberty Tunnels," was presented by Mr. C. K. Harvey, Assistant Engineer, Bureau of Bridges, Department of Public Works, Allegheny County, Pittsburgh, Pa.

The ensuing discussion was participated in by: C. H. Dorsey, Treas., The R. G. Johnson Company; W. E. Fohl, Consulting Mining Engineer; P. J. Freeman, Chf. Engr., Tests and Specifications, Allegheny County; Emil Hallgren, Engineer, Pittsburgh, Pa.; R. H. Helick, Maintenance Engr., Bureau of Bridges, Dept. Public Works, Allegheny County; Winters Haydock, Chf. Engr., Transit Commission, City of Pittsburgh; N. F. Hopkins, Civil and Mining Engr., Harrop & Hopkins; Arthur McGonagle, Consulting Engineer; P. W. Price, Prin. Asst. Engr., Bureau of Bridges, Dept. Public Works, Allegheny County; J. M. Rice, Consulting Engineer, Pittsburgh, Pa.; F. W. Ritchey, Asst. Engr., Bureau of Bridges, Dept. Public Works, Allegheny County; and the author.

It was moved and carried unanimously that a vote of thanks be extended to Mr. Harvey for his very interesting paper and to Messrs. Ritchey, McGonagle and Hallock for the valuable information given after the reading of the paper.

On motion, the meeting adjourned at 10:25 P. M.

K. F. Treschow, *Secretary.*

MINING SECTION

The regular bi-monthly meeting of the Mining Section of the Engineers' Society of Western Pennsylvania was held in the Blue Room, William Penn Hotel, Tuesday evening, March 30, at 8:25 P. M., Chairman N. F. Hopkins presiding, 42 members and visitors being present.

The minutes of the last meeting, held January 26, were read and approved.

There being no further business coming before the Section, the paper of the evening, on "Various Methods of Cutting Coal," was presented by Mr. W. R. Jarvis, District Manager, Sullivan Machinery Company, Pittsburgh, Pa.

The ensuing discussion was participated in by: Harry J. Lewis, Consulting Engineer, Pittsburgh; N. F. Hopkins, Civil and Mining Engineer, Harrop & Hopkins; Edward Steidle, Supervisor, Co-operative Mining Courses, Carnegie Institute of Technology; L. D. Tracy, Coal Mining Engr., U. S. Bureau of Mines; W. W. MacFarren, Mech. Engr., Pittsburgh; Graham Bright, Cons. Engr., Howard N. Eavenson and Associates; L. F. Crawford, Partner, Coal Mine Equipment Co.; E. H. Coxe, Mining Engineer; and the author.

On motion, duly seconded and carried, a vote of thanks was extended to Mr. Jarvis for his very interesting paper.

On motion, the meeting adjourned at 9:10 P. M.

K. F. Treschow, *Secretary.*

ORGANIZATION MEETING—ELECTRICAL SECTION

The organization meeting of the Electrical Section of the Engineers' Society of Western Pennsylvania was held in the Ball Room, William Penn Hotel, Wednesday evening, March 31, at 8:20 P. M., President W. E. Fohl presiding, 140 members and visitors being present.

The President opened the meeting with the following remarks:

"Gentlemen, this meeting has been called for the purpose of organizing an Electrical Section of the Engineers' Society of Western Pennsylvania. As you all know, in addition to the general activities of the Society and our general Society meetings, we have Civil, Mechanical, Mining, Steel Works, and Practicing Engineers' Sections; and now, in accordance with the will of the Society, we are about to add the Electrical Section. The present administration, of course, welcomes this extension of the activities of the Society. We make haste to disclaim, however, any particular credit for this extension. We look upon this as the crowning achievement of the administration which held office during the past year. The prime mover in that administration was, of course, the President, and he has also been the prime power in the organization of this Electrical Section.

"Pursuant to these activities of his, he was asked to head the Nominating Committee for officers for this new Section, and I shall now ask him to present the report of the committee and at the same time to give us a few remarks covering the history of the organization of this Section and anything else he may care to add. I, therefore, call upon Mr. Spellmire to address the meeting and upon his conclusion to present the report of the Nominating Committee. Mr. Spellmire."

Mr. Spellmire replied as follows:

"Mr. President and Gentlemen: For a number of years our Society has had in mind organizing an Electrical Section, and I cannot claim all the credit that our President has given me this evening for the reason that what has finally been accomplished has been the result of previous attempts made to bring into being this new Section. All that I did was to profit by studying the things that were done and were not done in former attempts. Among other difficulties in the past there has been a feeling that the formation of an Electrical Section of the Engineers' Society might trespass to a measurable extent upon similar engineering activities on the part of other bodies. Other organizations active in the promotion of the electrical art are the American Institute of Electrical Engineers, the Association of Iron and Steel Electrical Engineers, the Electric League of Pittsburgh and the Illuminating Engineering Society.

"The by-laws of our Society make the necessary provision for the installation of various sections of engineering activities. We are now approaching the fifty-year mark of our life. During this period there have been organized Sections covering Civil Engineering, Mechanical Engineering, Mining Engineering, Steel Works and Practicing Engineers. For about twenty-five years after the formation of the Society it constituted the only engineering activity, as such, in Western Pennsylvania. Subsequently, however, certain national engineering organizations with headquarters in the east extended their activities by organizing local chapters in various cities. This occurred with the A. I. E. E., A. S. C. E., A. S. M. E. and the A. I. M. & M. E. Their local chapters' activities extend over periods varying from one to fifteen years.

"In order to promote the best interests in engineering activity, harmony and efficiency, the local chapters of the national bodies made various arrangements. Thus, the Civil Engineers decided to hold no technical sessions in Pittsburgh, as the Engineers' Society filled this want. The American Institute of Mining and Metallurgical Engineers took about the same stand. The Mechanical Engineers decided to hold joint meetings with the Mechanical Section of the Engineers' Society. All this came about largely because the Engineers' Society was numerically much stronger than any one of the local chapters and also because the individuals held membership in both organizations. The Engineers' Society being established, supplied with headquarters and a paid Secretary, was a natural rallying point. Combined with this was the thought of the remote possibility of ultimately merging all activities with an Engineers' Society building, not unlike that of New York City. A plan is now in effect having in mind the forming of a Section to be known as the Illuminating Engineering Section to be merged with and joint meetings held with the local chapter of the Illuminating Engineering Society, a national organization.

"The A. I. E. E., being the oldest and numerically the strongest of the national local chapters, and because there was no Electrical Section of the Engineers' Society, maintained its separate activities. However, many members of the A. I. E. E. were members of the Engineers' Society. Also many applicants for membership in the Engineers' Society expressed a desire for registration in an Electrical Section. There being no Electrical Section, the Society suffered embarrassment. Furthermore, the rapid development of the electrical art in more recent years led to frequent calls for engineering papers and discussions on electrical subjects, and which actually took place, although there was no organized Electrical Section for the presentation of such papers.

"After a careful survey of the activities of the local electrical organizations it was felt that each of these had a field of activity more or less segregated and that the Engineers' Society could continue its electrical activity through a regularly organized section with little or no conflict. However, the work of the A. I. E. E., being the most closely allied with the activities of the Engineers' Society, and there being many members common to both organizations, it was decided after various conferences with the A. I. E. E. officers and directors that much could be gained by merging the activities of the two organizations, bringing about an arrangement similar to that existing between the Engineers' Society and the American Society of Mechanical Engineers whereby joint technical meetings would be held; also using the Engineers' Society rooms as headquarters and its staff to assist. Such a united effort renders available the sources of both organizations in providing papers and programs. Having all this in mind, the routine requirements of the Society were complied with and the Electrical Section formed. Also there being a common membership of many in both Societies, favorable consideration has been given to the thought of having the same member elected to the Chairmanship of each Section, and that to some extent the Executive Board of both organizations be represented by the same individuals, such an arrangement being conducive to more closely allied effort."

The following report of the Nominating Committee was presented by Mr. W. B. Spellmire, Chairman:

Mr. W. E. Fohl, President,
Engineers' Society of Western Pennsylvania:

DEAR MR. FOHL:

Your committee appointed to make nominations for the members of the Executive Committee of the newly formed Electrical Section of the Engineers' Society is pleased to submit report as follows:

Chairman..George S. Humphrey
Vice-Chairman ....W. C. Goodwin
Directors.. M. E. Skinner, D. M. Simons, Andrew Pinkerton, J. A. Malady, R. L. Rapp

All these men, both officers and directors, are members of both the Engineers' Society and the A. I. E. E.

MAURICE R. SCHARFF,
BARTON R. SHOVER,
W. B. SPELLMIRE, *Chairman,*
Nominating Committee.

President Fohl: "You have heard the report of the Nominating Committee. Are there any further nominations?"

On motion, the nominations were closed and the Secretary instructed to cast a unanimous ballot for those nominated, and they were thereupon declared elected, and Mr. George S. Humphrey, newly elected Chairman, was called to the Chair.

Chairman Humphrey: "Mr. President and fellow-members of the Engineers' Society of Western Pennsylvania, I wish to thank you for the privilege of becoming the first Chairman of the Electrical Section of the Engineers' Society of Western Pennsylvania. I believe the Section just now organized will become the largest and strongest of the six Sections of the Society. I was very glad the question of affiliation between these two organizations came up again during my administration as Chairman of the Pittsburgh Section and that I have been able to have some part in bringing about an arrangement for such co-operation, because I believe this will work toward closer co-operation between engineers of all branches, make the engineers of greater influence in the community and bring to realization more quickly the dream which Mr. Spellmire mentions, when we will some time have an engineering club building in this city.

"Mr. Spellmire mentions that the Engineers' Society has nearly two thousand members. I might say that the Pittsburgh Section of the Institute has about one thousand members, and there are only about ninety of them who are members of both the Engineers' Society and the Pittsburgh Section of the Institute. Adding the influence of the nine hundred members of the Institute who are not members of the Engineers' Society to the influence of the Engineers' Society will surely work to the benefit of engineers and engineering in general in this district.

"Speaking now as a member of the Institute to the Engineers' Society, I wish to say that the officers of the Pittsburgh Section are extremely proud of their Section. It is the largest Section of the Institute outside of New York City. It has the largest attendance of any Section of the Institute outside of New York City, the average attendance for six monthly meetings held so far this year being 250, the smallest being 150 and the largest 368.

"Your Committee of Arrangements for this meeting, Mr. Spellmire, Chairman, wished to have the first meeting of the Electrical Section an outstanding one; and in considering the speaker their minds went back three years to a speaker at the banquet during the Spring Convention of the American Institute of Electrical Engineers here in Pittsburgh. They knew this gentleman had made talks many times and in many places before many organizations of very different purposes and covering a very wide field. He has been very active for many years in the National Electric Light Association, having been Chairman of the Technical Section at one time; and also very active in the American Institute of Electrical Engineers, having presented papers and held various offices, finally becoming Vice-President. He is also very active in the Western Society of Engineers of Chicago. In addition to all these engineering activities, he has been very much interested and very active in civic and social affairs of many kinds. I had the pleasure of entertaining him this afternoon. I naturally expected that he would want to see some of our large steel plants or power houses for which this district is famous. I was very much surprised to find that what he was interested in today was Pittsburgh's civic problems, so we spent the afternoon looking those over. This gentleman also has a considerable reputation as a playwright, I understand. I remember at the Annual Convention of the Institute in Chicago, three years ago, there was an entertainment from his pen which was certainly very interesting and enjoyed by all.

"Your committee got in touch with this gentleman, and on very short notice—most of the arrangements having been carried on by long-distance telephone—he readily consented to come down here and talk to us. I might say that in addition to all his other activities that I have mentioned he has for more than fifteen years been Chief Electrical Engineer of the Commonwealth Edison Company of Chicago and is largely responsible for the many developments of an engineering nature that have been made by that wonderful organization, which is the largest power company of the world. The subject of the evening is 'Superpower, the Giant Killer,' and this subject will be presented by Mr. R. F. Schuchardt, of the Commonwealth Edison Company, Chicago, whom I am honored to present at this time."

The paper of the evening was then presented by Mr. Schuchardt.

A vote of thanks was extended to Mr. Schuchardt for his very interesting paper.

The Chairman announced that, in accordance with the regular custom, the Committee on Constitution and By-Laws for the Section would be appointed by him in the near future.

The meeting adjourned at 10:40 P. M.

K. F. TRESCHOW, *Secretary*.

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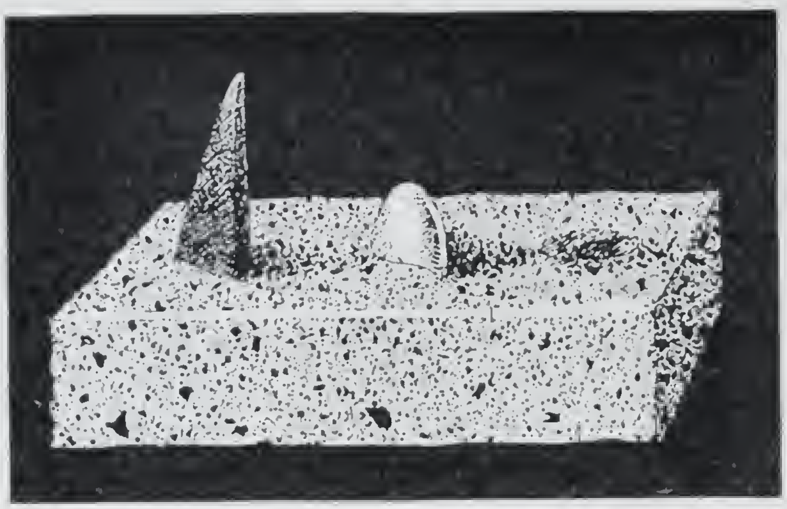

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OF THE

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CONTENTS

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All papers, upon their acceptance by the Publication Committee, become the property of the Society, and it lies within the discretion of the Committee to publish them in whole or in part. The Society, however, does not hold itself responsible for opinions expressed by its members.

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Franklin Institute. Journal

Gluckauf

Great Britain—Patent Office. Illustrated Official Journal

Heating and Ventilating Magazine

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Institution of Mechanical Engineers. Journal

Institution of Mining Engineers. Transactions

Iowa Engineering Society. Proceedings

Iron Age

Iron and Coal Trades Review

Iron Trade Review

Journal of Industrial and Engineering Chemistry

Journal of the United States Artillery
Keramische Rundschau
L'Association des Ingeniurs. Annales
Liverpool Engineering Society. Transactions
Mechanical Engineering
Military Engineer, The
Mining Congress. Journal
Mining and Metallurgy
National Engineer
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Popular Engineer
Popular Science Monthly
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SAFETY AND CONSTRUCTION STANDARDS FOR TRANSMISSION LINES*

By James S. Martin†

The development of any field of engineering activity in its evolution from the rule-of-thumb stage to a finished science is usually marked by certain well-defined steps. When a new line or type of construction is taken up, it is at first generally turned over to the so-called "practical" men, who proceed along cut-and-try and rule-of-thumb methods to design and build the necessary structures, machines, or whatever else is needed to bring about the results desired.

As the art develops, and the need for continuous and uninterrupted service increases, the failures and interruptions to service, resulting from this method of design, become more and more annoying, costly, and even dangerous. Those who are interested in the subject then turn their attention to the question as to whether it is possible to design the necessary structures or machines so as to eliminate these failures. This step is nearly always taken in the face of opposition from the "practical" men who have been engaged in the design and construction of the necessary apparatus or structures.

Then follows what may be termed a period of chaos, when many theories are advanced and advocated or assailed. As these theories are tested in practice, the false are gradually eliminated, and the general practice becomes more nearly standardized. The men who at first were in charge of the design and construction, and who have refused to advance with the development of the art, are gradually pushed aside to make room for more progressive men.

The next stage is one of apparent fossilization, when everyone seems to consider that the highest state has been reached and that further development is unnecessary or impossible. It is at this stage that the products become commercially standardized, and any further development must meet with the combined opposition of those whose minds have become set and of the business men whose money is invested in the manufacture of the materials used in the structures

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involved, except in cases where those interested have been compelled to keep their minds open to meet competition.

While the opposition to advancement at this last stage retards growth to some extent, yet it serves the useful purpose that any change or improvement suggested must be sound, and based on correct principles, to stand any chance of adoption.

We have gone into this discussion of the stages in the history of engineering development for the reason that we will find that the different branches of construction used in the distribution of electric power have reached different stages; and as we intend to suggest some changes in the present methods, it will be necessary to keep in mind the state of the art which has been attained in the branch under consideration.

In this discussion it is necessary for us to limit ourselves to the overhead distribution of power. Underground distribution is in another class as to type of construction and will not be included. We will, however, go into a discussion of the construction of outdoor substations, since this subject is so closely related to that of transmission lines, the same principles governing both to a large degree, and such a substation generally forms one or both of the terminals of a transmission line.

The need for reliable safety standards in transmission-line construction is growing greater every year. Electricity has become such an important factor in our every-day life that an interruption to service which would have been passed over a few years ago with possibly some sarcastic remarks and a telephone call to the electric company, and then forgotten, would now cause such annoyance and probably financial loss that the lives of those who are in charge of the service are made miserable for some time, and the affair is not soon forgotten by anyone concerned.

A few years ago, many of the stores, theaters, and other large establishments, as well as a majority of the manufacturing plants, generated their own power. The economy of central power-stations has led to an almost universal abandonment of these small stations, and to the purchase by their former owners of current at lower rates than their own cost of production from the central power companies. Under the former circumstances, the inconvenience and loss involved

in a breakdown fell on the few people served by that small station. In the present case, a serious breakdown involves a whole city.

It is apparent, therefore, that a construction which may have passed as reasonably safe a few years ago, may be entirely inadequate for present conditions. In view also of the projects for "superpower" installations, it is imperative that a closer study of safe and economical methods of construction be made. In our own state of Pennsylvania, the Public Service Commission is taking steps toward the revision of the safety code for electric transmission, while the same thing is occurring in other states.

In handling this question, we shall take up the different items in the order in which they will be met in designing a line.

The first point which will come up for consideration is the size and type of wire to be used. In making this statement we are passing over the fact that the voltage and amperage of the line must be determined before the type of wire can be decided upon. This point, however, is so involved with the commercial aspects of the case as to be outside the scope of this paper.

In selecting a wire, the size should be such that it will carry at the required voltage the necessary number of amperes without overheating.

The material selected will have much to do with the size of the wire, except in the case of very high voltages, where, in order to reduce the corona losses, a wire of such size will be needed that conductivity becomes a matter of secondary importance, since the wire will be so large that almost any metal will give the required conductivity. Up to 66,000 volts, however, the corona losses are not large enough to cause any serious waste, and the conductivity of the wire is the deciding factor.

The first question to decide is, what limit shall be placed on the temperature of the wire? It has been found that hard-drawn copper wire will not anneal at a temperature of 200 degrees F. At 250 degrees it will eventually be annealed. At 300 degrees it becomes annealed in a short time, while at 400 degrees it will become perfectly annealed in a fraction of a minute. It is apparent from this that 200 degrees F. should be the limit to which copper wire should ever be heated.

In steel-reinforced, aluminum wire, where the steel core is depended upon to carry all the load, the heating may be carried much higher. While temperatures up to 600 degrees F. are not injurious to the steel, the writer is doubtful as to the effect of such a temperature on the zinc coating of the steel wire, and believes that a limit of 300 degrees should be placed on wire of this type.

In the case of mixed strand "copperweld" and copper wire, since the copper takes a share of the load, this wire should be considered the same as copper in the matter of heat limits. "Copperweld" wire has taken temperatures up to 900 degrees without apparent injury.

As to the economy of using a high voltage with a lower amperage, as compared with using a lower voltage with a higher amperage, the writer does not believe that any set empirical rule can be given. The general recent practice of electrical companies has been to choose the former of these methods. Voltages in main transmission lines have risen till lines of 250,000 volts are now being projected. This practice allows a smaller wire to be used, but requires a greater separation of wires and greater clearances from the towers, which means that the towers must be designed to take greater torsional stresses. The latter practice requires the use of larger wire, which can be drawn up to give less sag, giving higher tension in the wires; but, to offset this, the towers will be shorter and the spans longer, so that we must balance these factors against each other in each individual case before a definite conclusion can be reached. It is probable that the general economical balance will be in favor of the higher voltage, but each case must be analyzed for itself.

Fig. 1 indicates the temperatures of hard-drawn copper wire carrying current, based on atmospheric temperature of 90 degrees F.

Having determined the size and type of conductor wire, the next question is the matter of the ground wire. The usefulness of a ground wire as a protection against lightning is a matter of dispute. It would seem that its efficiency for this purpose depends on the frequency with which it is grounded. The more frequently it is grounded, the higher its efficiency. One thing is certain, however— the ground wire may be a mechanical help or it may be a mechanical and electrical hazard. The practice of placing over the conductors a ground wire having less strength than the conductors is a very serious mistake. The storm of February 19 and 20, 1924, revealed this point.

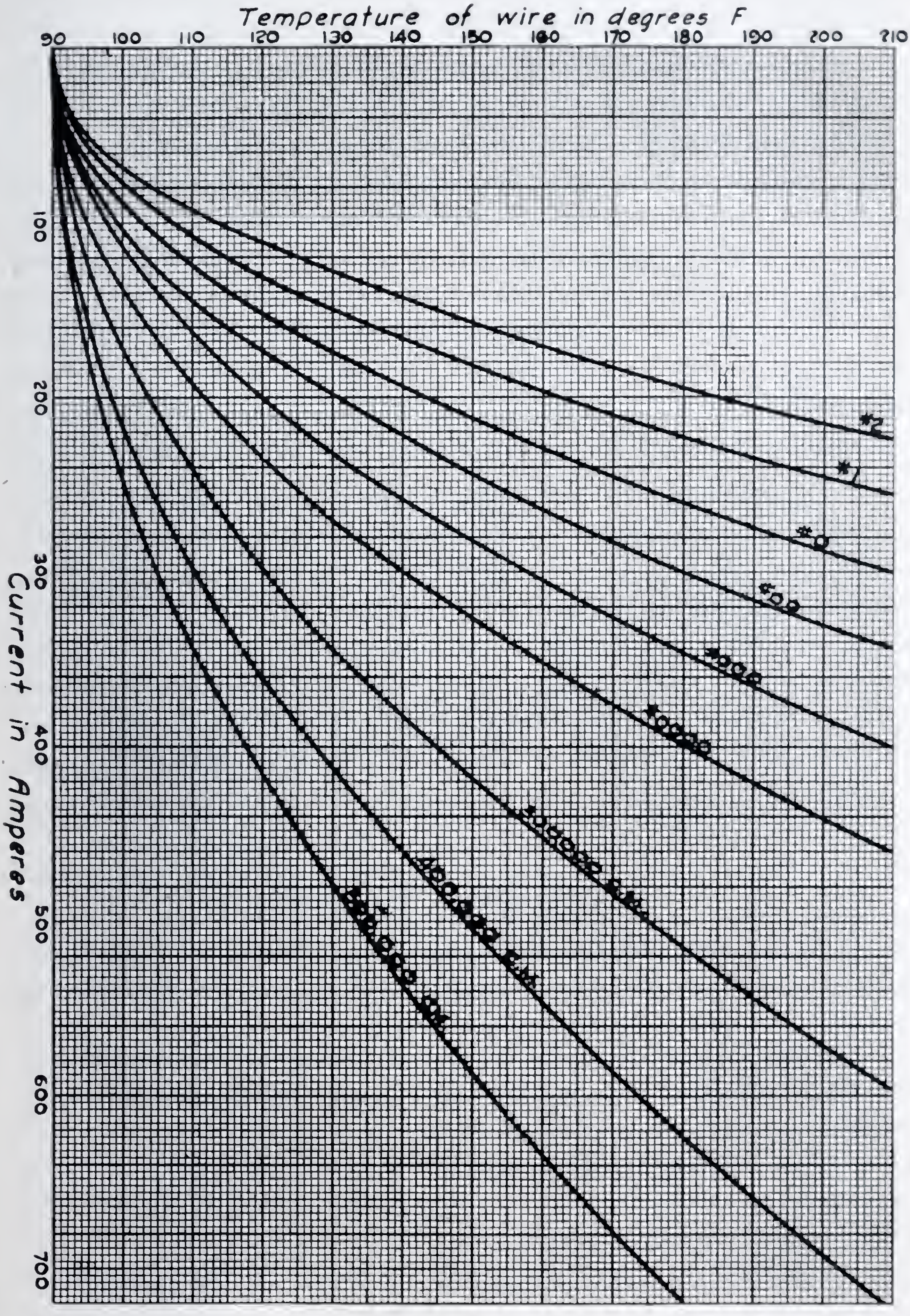

Fig. 1. Temperature of Hard-Drawn Copper Wire.

The wires were overloaded with ice. Since the ground wires had no benefit from the rise in temperature due to the electric current which the conductor wires had, the overload on the ground wires was greater than on the conductors. The tendency of the ice was to fall off the conductors first. One result was that the ground wires were carried down too close to the conductors. Another result was that the lighter ground wires were unable to resist the strain of the overload, and many of them broke and fell over the conductors, grounding them. See Fig. 2.

Our practice up to that time had been to use a lighter wire but of stronger material, so that the calculated sag would be the same for the ground wire and the conductor. Since that storm the writer has changed his views. The lesson learned was that the ground wire

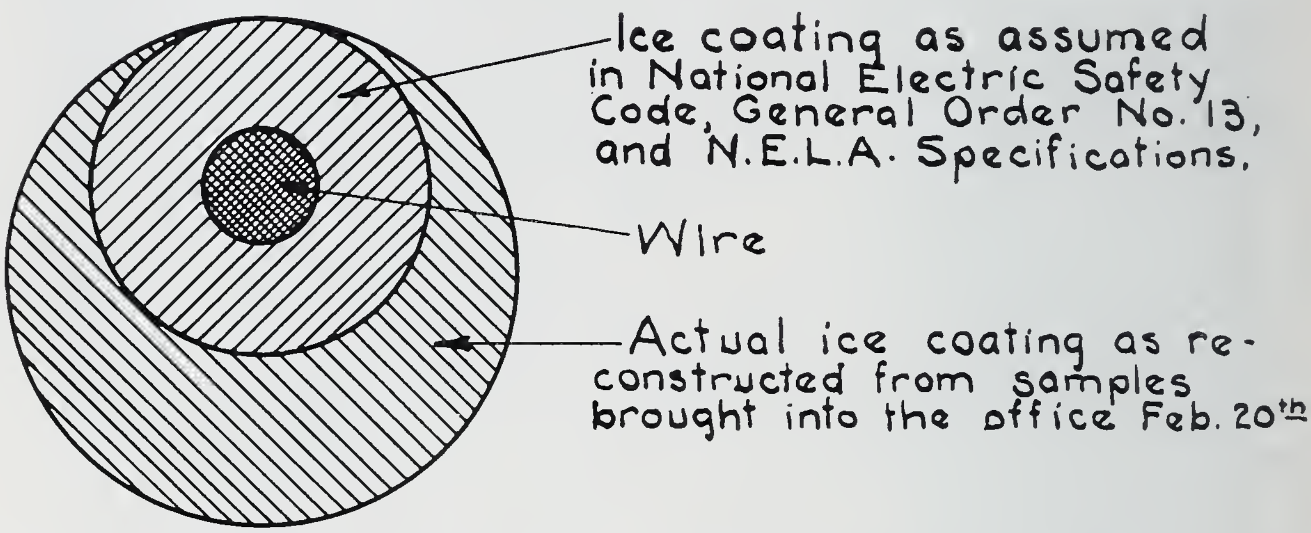

Fig. 2. Graphic Representation of Overloaded Condition of Wires During Storm of February 19-20, 1924.

should be stronger than the conductor and capable of being sagged so that when the ground wire is loaded with ice and the conductor is unloaded the distance between them will be safe.

If the ground wire is made strong enough to be safe against breaking, it will tend to act as a head guy to the suspension towers and become a source of strength instead of a hazard.

As to what material to use for ground wire, experience with galvanized steel wire in the Pittsburgh district has not been very encouraging. It may work out all right elsewhere, but with the atmospheric conditions here it does not take very long for the elements to get through the thin zinc coating. We have not had so much difficulty with the steel-reinforced aluminum wire, where the steel wire

is protected by two or three layers of aluminum wire, but steel-reinforced aluminum is in its very nature unsuited for use as a ground wire, as aluminum is a very poor transmitter of a lightning charge.

Copper wire would be all right as far as conductivity is concerned, but a lightning stroke is apt to burn it in two, and besides, since the conductors are usually made of copper wire, it would be necessary to place a heavier stress on the ground wire to meet the conditions which we have previously stated, which would require a heavier wire for the ground than for the conductors, placing heavier stresses in the towers, and adding to the cost of the line.

Silicon bronze wire apparently meets some of the conditions for an ideal ground wire, but the writer has not been able to obtain from the manufacturers sufficient information as to its characteristics to enable him to make any recommendation as to this wire.

Copper-steel wire, in which there is a reliable weld between the copper and steel, is preferred by the writer for use as a ground wire. In the early days of the manufacture of this product some of the wire produced was not satisfactory, but the process of manufacture has been developed to a point where a reliable product can be obtained. The only trouble with this wire is that, in dragging long stretches of it over the ground, patches of the copper coating are sometimes worn off, exposing the steel. This is not so likely to happen as in the case of galvanized wire, where the thin coating of soft zinc is more easily worn off.

One advantage in the copper-steel wire is that, being stronger than copper wire, a lighter wire can be selected, which at the same time can meet the conditions which we have laid down.

Having selected the wire, the next step in the designing of the line is the proper spacing. Nearly all the specifications which the writer has seen have given some empirical formula for the separation of wires. No reference to or allowance for the variations in the characteristics of different types of wire has been made. A span strung with "extra high tensile copperweld" wire would be treated by the same formula as one strung with soft-drawn copper. This sometimes results in unnecessarily expensive construction, and at other times allows dangerously close spacing.

We will take a concrete example to illustrate this point. General

Order No. 13 of the Pennsylvania Public Service Commission requires a separation between wires in both horizontal and vertical direction of one inch for each 20 feet of span plus one inch for each foot of normal sag. Assume a No. 0000 stranded copperweld wire to be strung over a span of 1400 feet, with a sag which will give a maximum tension of 4500 pounds at zero F., with a ½-inch coating of ice and a wind pressure of eight pounds per square foot. This will give a normal sag of 88.10 feet at 60 degrees The separation according to this rule must be $(1400 \div 20) + 88.10$ inches $= 158.10$ inches or 13.175 feet. If one wire is hanging above another, the temperature being zero, and the wires being loaded with a ½-inch coating of ice but no wind, and the ice load drops off the lower wire, the sag in the wire will be reduced 2.689 feet, or from 88.979 feet to 86.290 feet. This will reduce the clearance between wires to 10.486 feet. This is more than is needed for safety. Considering the problem rationally, let us add 50 per cent. to the difference between the sag of the ice-loaded wire and that of the unloaded wire, to allow for the jump of the wire as the ice drops off, and add 2.75 feet for safety against flash-over. We would have 1.5×2.689 feet $+ 2.75$ feet $=$ 6.783 feet, or we will say 7.0 feet as the safe separation, instead of 13.175 feet as required by General Order No. 13.

Taking another case, assuming a No. 0000 "extra high-tensile copperweld" wire, strung to give a maximum stress under ice- and wind-loading conditions of one-half the ultimate strength, or 10,470 pounds. In this case the normal sag for a 1400-foot span at 60 degrees would be 24.139 feet. The separation allowed by General Order No. 13 would be $(1400 \div 20) + 24.139$ inches $= 94.139$ inches, or 7.845 feet. In this case the sag at zero temperature with a ½-inch coating of ice but no wind would be 32.971 feet; while, at the same temperature with no ice, it would be 21.543 feet, making a difference of 11.428 feet. Taking the same circumstances as assumed for the first example—that of one wire over the other—if the wires are given a separation as allowed by the rule (7.845 feet) and the ice load falls off the lower wire, it will rise 11.428 feet, and at the low point of the curve will be 3.583 feet above the upper wire, giving two points of contact, and making a short-circuit absolutely certain.

Other examples could be piled up to prove the writer's contention, that no empirical formula for separation of wires can be devised

which will not give ridiculous results, but this one problem brings the point out so clearly that we will not burden you with any further proof.

The excuse given for these empirical formulæ is that they are easy to apply and can be used by anyone, even though he is not versed in mathematics or in the methods of calculating sags.

This position is absolutely untenable. Why should an important matter which involves the continuity of service, and the safety of human lives be left to be handled by any Tom, Dick or Harry?

It is a well-known fact that the most dangerous animal at large is the man who possessses a smattering of engineering knowledge and a Carnegie "Pocket Companion." To turn an untrained man loose with an engineering formula is as risky as to set free in the streets a seven-year-old boy with a Colt "automatic." The sooner we get the business men of the country and the public in general to realize that engineering problems must be handled by engineers, the more rapidly will we progress toward reasonable and safe construction.

The writer would propose the following rule for separation of conductor wires:

Vertical separation of conductors shall be 1.5 times the difference between the sag of the wire loaded with one-half inch coating of ice without wind, and the sag of the unloaded wire at the same temperature, plus 0.5 inch for each kilovolt or fraction thereof carried in the line.

Horizontal separation of conductors shall be such that when the wire on the windward side is loaded with ½-inch coating of ice, and the opposite wire is bare, a wind pressure up to eight pounds per square foot on the projected area will not bring the wires closer than 0.5 inch for each kilovolt carried in the line. No pendulum swinging of the wires need be considered where the sag is over six feet.

The distance of wires shall be the actual distance at their closest point, and shall not necessarily be the points where a horizontal or vertical projection of the wires shows their lines crossing.

This rule sounds complicated, and it is in practice, but the writer believes it will cover the needs of the case as well as any rule or formula can be made to do.

At this point we would mention the matter of the critical span.

It seems that at or very near the span in which the unstressed length of the wire is equal to the length of the span—or, in other words, a span such that when the sag is being calculated the unstressed length factor of the wire is equal to 1.000—seems to be a turning-point in the action of the wire. In making a series of calculations, as you approach this point from the shorter spans the number of intervals passed over in the tables for any certain number of degrees of temperature increases. After passing this point in coming to the larger spans, the number of intervals decreases. Besides this, it seems that at this point the wire is affected more by changes in loading than at any other point, and the only case we have experienced where a wire losing its ice load jumped up into contact with the wire above it has been a case where the span was of such length that the unstressed length of the wire was about equal to the span. Besides these, there are many other peculiarities found while making calculations of sags and stresses, and these have brought the writer to the conclusion that if the sag chart of a wire for any temperature is plotted to a large enough scale, and the calculations made for close enough intervals, it will be found that instead of the line following a curve at this point there will be an intersection of two curves. Experience with the storm of February 20, 1924, has led the writer to have this critical span marked on all charts which have been calculated since that time. In laying out a transmission line the writer would consider this critical span to be the most dangerous, and such a length of span should be avoided if at all possible, with the preference, of course, in favor of longer spans.

While the rule just given for vertical separation will generally give about the same vertical separation on long spans as on short ones, yet it is the writer's opinion that the tendency of a wire to jump in case of ice falling off a long span is less than in a short span, and that a smaller vertical separation should be allowed in a longer than in a shorter span, except for the possibility of the ice falling from one-half the span while remaining on the other half.

While the question of ground clearance does not logically belong at this point in our discussion, yet, since we are considering the matter of clearances, we will take up this whole subject and complete our discussion of it at this time.

Many of the specifications for clearance of wires from the

ground, over railroad tracks, trolley lines, and other electric wires are subject to the same objections as those just made against the rules for separation of conductors. They are products of the time when 300-foot spans for steel towers and 150-foot spans for poles were considered the limit. Longer spans were looked upon with suspicion, and the construction of such spans was penalized by insisting on increased clearances when the span length exceeded these limits.

The writer fails to see any necessity for such increases in clearance in long spans. While there may be reasons for a slight increase in ground clearances to allow for swinging of suspension insulators, in case of a broken wire in an adjoining span, yet the increased sag in such a case is not relatively as great in a long span as in a short one, and an adjustment should be made on the basis of the type of insulators used, rather than on the length of span.

The usual classification of ground clearances is about as follows: 1. Railroad tracks. 2. City streets and main traveled highways. 3. Country roads. 4. Places inaccessible except to pedestrians.

While this classification is a fairly good one, yet the definitions of the classes should be more clearly explained than is now done. For example, some engineers place in the last class all fields and spaces not occupied by roads. This is not a safe interpretation. Nearly all fields at some time or other are used for hay or grain fields. When you consider that a man is at some time likely to be standing on a load of hay or wheat, and wielding a pitchfork right under the wire, it is easy to see that an open field may require a greater clearance than an ordinary roadway.

The writer would insist upon the following interpretation: All spaces where the slope is not more than 30 degrees shall be considered accessible to wagons, except where the conditions of surrounding territory are such as to make the place inaccessible.

The ground clearance requirements given below are as given on pages 91-92 of the National Electrical Safety Code, Ed. 3, October 31, 1920, published by the United States Bureau of Standards in 1921.

CLEARANCE FROM GROUND OR RAILS

[The numbers represent the clearances in feet to be provided by the conductors or wires at the heads of columns, above places specified at the side of the table.]

Nature of crossing	Clearance for the several groups—			
	For signal, guys, spans, lighting-protection wires, supply lines or services less than 300 volts to ground, messengers	For 300 volts to ground up to 15 000 volts	For 15 000 to 50 000 volts	For trolley contact wires (not feeder cables)
Crossing above track rails of railroads handling freight cars where brakemen are permitted on top..........	*a*27	*a*28	30	*b*22
Crossing or along streets or alleys in urban districts or crossing street or roads in rural districts (over the traveled way) or over track rails not included above....................	*c, d*18	20	22	*e*16
Along roads in rural districts..........	*c*15	18	20	*e*16
Crossings above spaces or ways accessible to pedestrians only...........	*f*12	15	17	*e, g*16

a This clearance may be reduced to 25 feet when paralleled by trolley contact conductor on the same street or highway.

b In communities where 21 feet has been established, this clearance may be continued if carefully maintained. The elevation of the contact conductor should be the same in the crossing and next adjacent spans.

c This does not apply to guys which are not carried over, but merely beside streets or alleys, unless also over driveways. Over roadways to residence garages, 10 feet is sufficient clearance. For conductors along roads where the location of the pole relative to fences, ditches, embankments, etc., is such that the ground under the line will never be traveled except by pedestrians, the clearance above the ground may be reduced to 10 feet for signal conductors and to 12 feet for supply conductors.

d Where with guys crossing streets or alleys the section of the guy concerned is effectively insulated from the highest voltage to which it is exposed, up to 7,500 volts, this value may be decreased, in urban districts, to 16 feet at the side of the traveled way.

e This clearance is the minimum clear height in the middle of the trolley contact conductor span, and the point of support at the trolley hanger should be at a height not less than 18 feet above the track rail, thus allowing 2 feet for the total maximum sag at 60° F in span wire and trolley contact conductor. For trolley contact conductors of more than 750 volts to ground this clearance shall be increased by 2 feet.

f Signal conductors of less than 150 volts to ground need have only 10 feet clearance. Supply or other wires (except trolley contact wires) if of less than 150 volts to ground need not have more than 10 feet clearance at entrance to buildings. For guys, 8 feet will be sufficient and no clearance is required for anchor guys not passing across pathways, or for those parallel with sidewalk curbs where traffic guards are provided.

g Trolley contact conductors for industrial railways where not along or crossing over roadways may be placed at a less height if suitably guarded.

Increased Clearances—Greater clearances . . . shall be provided under the following conditions:

(1) For spans longer than 150 feet the clearances shall be increased by 1 inch for each 10 feet of the excess between 150 and 300 feet and by 1 inch for each 20 feet of the excess beyond 300 feet.

(2) For voltages greater than 50 000, the clearances given shall be increased at the rate of 0.5 inch for each 1000 volts of the excess.

(3) Where the lowest supply conductor at a crossing over track rails is supported by suspension insulators the initial clearances shall be sufficient to prevent the minimum clearances over rails . . . from being reduced more than 10 per cent through the breaking of a conductor in either adjoining span.

The arrangement of insulators so that they are restrained from displacement toward the crossing will avoid the necessity of any increase over the clearances given.

(4) The above increases are cumulative when more than one applies.

The criticism the writer would offer of these requirements is that in several cases they start too low and end up too high. In Fig. 3 is a chart giving the clearances according to the National Electrical Safety Code and the requirements of the Public Service Commission of Pennsylvania, General Order No. 13, for railroad crossings. In this chart the assumed loading of wires is 0.5-inch coating of ice, but no wind; the ratio of the vertical to the horizontal scale is 4 to 1; and the assumed voltage for clearance calculations is 60,000.

In contrast to this the writer would submit the following:

1. *Railroad Crossings.* All spans crossing railroad tracks shall be supported by strain insulators or pin insulators. The vertical clearance between the top of the rail and the lowest conductor wire, measured at the point where the wire crosses the rail, shall not be less than 27 feet plus 0.5 inch for each kilovolt carried. Clearance shall meet the larger requirement of the two following conditions:

a. Wire loaded with a one-half inch coating of ice but no wind at 32 degrees F.

b. Wire unloaded at the highest temperature to which the current will raise the wire at summer heat. For ordinary conditions in Pennsylvania this temperature may be taken at 120 degrees F.

For trolley contact conductors or trolley feeders, clearance from rail may be reduced to 22 feet.

2. *City Streets and Main Traveled Roads.* Clearance of lowest conductor wire above the surface of the roadway shall not be less than 23 feet plus 0.5 inch for each kilovolt carried in the line. Clearance shall be considered under the same conditions specified for railroad tracks. When wires are strung on suspension insulators a broken wire in the adjacent span shall not decrease the above specified clearance by more than five feet.

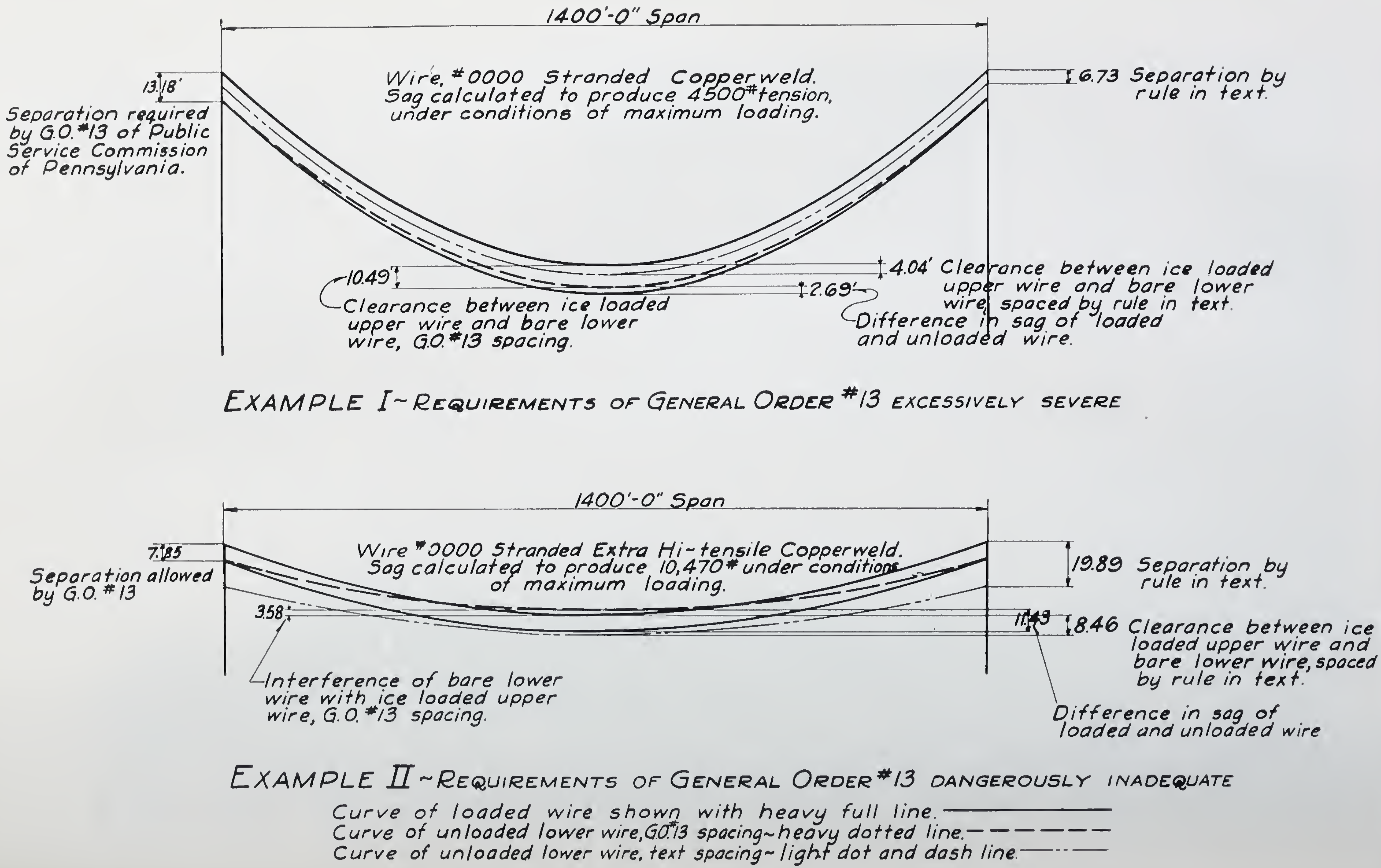

Fig. 3. Diagram Showing Dangers of Using Empirical Clearance Formulæ.

3. *Rural Roads and Open Fields.* Clearance of lowest conductor wire above the surface of the roadway or ground shall not be less than 22 feet plus 0.5 inch for each kilovolt carried in the line. This clearance shall be taken at the highest temperature to which the current will raise the wire at summer heat. Clearance with the wire loaded with 0.5-inch coating of ice at 32 degrees F. may be three feet less than the above clearance. When wires are strung on suspension insulators, a broken wire in the adjacent span shall not decrease the above clearances by more than four feet.

4. *Spaces Accessible to Pedestrians Only.* Clearance of lowest conductor wire above the ground shall not be less than 15 feet plus 0.5 inch for each kilovolt carried in the line. Clearance shall be taken at the highest temperature to which the current will raise the wire at summer heat. Clearance at 32 degrees F. with a 0.5-inch coating of ice may be two feet less than the above specified clearance. When wires are strung on suspension insulators, a broken wire in the adjacent span shall not reduce the above clearances by more than three feet.

The writer's reason for allowing a reduction in clearance in the last two cases for ice loading at 32 degrees is that in such localities the chances that anything which requires the maximum clearance will be passing under the wire at a time when wires are loaded with ice are extremely remote, while in the first two cases the traffic at such a time will be about the same as at any other time.

In considering a wire broken in an adjacent span, the distribution of the increased sag to the succeeding spans till a strain insulator is reached shall be considered. The writer's practice in this case is to add the length of the suspension insulator to the unstressed length of the wire in the span adjacent to that in which the wire is broken, and to consider the longitudinal deflection of the suspension insulators at the other end of the span as increasing the length of the span, and calculating the sag in the usual way. The weight of the insulator will cause a special deflection at that point, but, with the stresses to which these wires are usually drawn, this deflection has very little effect on the sag of the wire. See Fig. 4.

In the matter of clearances of wires in one line over wires of another line carried on separate supports, the writer would suggest the following:

Clearance of conductors in the crossing span over the wires in the span crossed shall not be less than four feet plus 0.4 inch for each

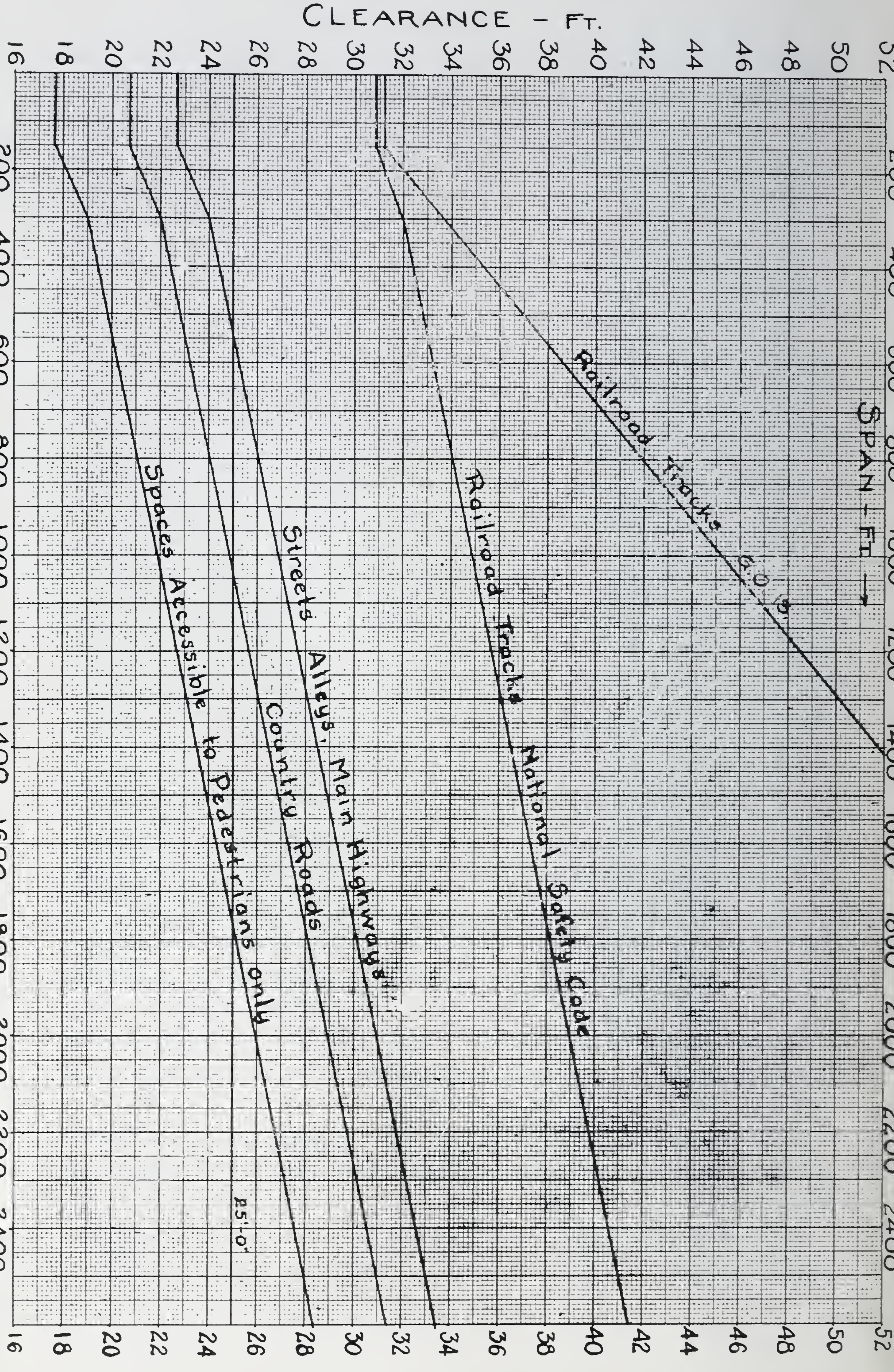

Fig. 4. Ground Clearance for 66-Kilovolt Wire.

kilovolt or fraction thereof carried in the line having the greater voltage. This clearance shall be considered as occurring when the wind is blowing transverse to the span crossed, the wire being considered as bare or loaded with ice, whichever condition raises it to the highest point, while the wires in the crossing span shall be considered as covered with 0.5-inch coating of ice.

Some may object to these specifications on account of their complications. They are complicated, but no more so than the problem which is to be solved. The designer of a steam-turbine or an electric generator does not decline to use a formula on account of its being complicated. The use of simple formulas in these cases, as in the separation of conductors, will often lead to ridiculous results, which are not always on the safe side of the mark.

In the discussion of the National Electric Safety Code, Handbook Series No. 4, page 120, the following statement is made: "The greater clearances called for where spans exceed certain minimum lengths are necessary because of the greater sags in longer spans due to ice loading or extreme temperature rise."

This statement as to the increased sags due to ice loading and extreme temperature rise is not correct. To prove this let us take two concrete examples. We will assume one of the worst conditions, if not the very worst condition, likely to occur—that is, a span supported by a strain insulator at one end and a suspension insulator at the other; the wire loaded with ice and broken in the span adjoining the end supported by the suspension insulator. For this computation we will assume a No. 0000 stranded hard-drawn copper wire sagged to give a stress under maximum loading of 4600 pounds.

The first span, let us say, is 200 feet long, the temperature is 32 degrees, and the suspension insulator is three feet long. The sag under such conditions is 1.688 feet. If the wire in the adjacent span is broken and the length of the suspension insulator is added to the length of the wire, the low point of the wire will be 11.429 feet below the low point before the wire in the adjacent span was broken. Taking the extra weight of the suspension insulator over the weight of an equal length of wire into consideration, the decrease in ground clearance will be 11.387 feet due to the breaking of the wire in the adjoining span.

Taking the same conditions in a 1500-foot span, we find that the

sag under the conditions named, before the wire in the adjoining span has broken, will be 104.647 feet. The reduction in ground clearance due to the breaking of the wire in the next span will be 6.028 feet, or about 53.4 per cent. of the decrease in the short span. See Fig. 5.

In taking up this problem we have assumed the severest conditions, but the same principles will hold good for any of the conditions which will affect the sag, demonstrating that a long span will "stay put" better than a short one, and if there is any need for increased clearances it is in the short spans rather than in long ones.

In the matter of low-voltage or moderate-voltage pole lines which follow the fence lines at the side of the road, and are located in such a position that no vehicles can ever pass under them, the writer would consider them entitled to consideration as being over spaces accessible to pedestrians only, except where they cross over an incoming road.

Lines paralleling railroad tracks, on which derricks and cranes are apt to operate, shall be given such clearance that the longest boom on any of the derricks or cranes used can not reach closer to the charged wires than five feet plus 0.5 inch for each kilovolt carried.

Clearance over buildings shall not be less than 10 feet plus 0.5 inch for each kilovolt carried. This clearance shall be taken at the temperature of the wire in summer heat, but the clearance at 32 degrees with a 0.5-inch coating of ice on the wire shall not decrease the above minimum by more than three feet.

The clearances of conductors from supporting structures have been pretty thoroughly gone over by others, and it will hardly be worth while to spend much time here in discussion of these. There is one point, however, which should be brought out. That is the matter of clearance of the ground wire from conductors. It is a common practice in designing towers to consider the suspension insulators, where such are used, as adding to the distance between the ground wire and the top conductor, and the distance between the connections on the tower for the ground wire and top conductor is shortened by an amount equal to the length of the suspension insulator. This is all right where the suspension insulators are used, but in some cases it becomes necessary to use strain insulators on towers designed to be suspension towers. Wherever a line is so laid out that at various points this becomes necessary, it is better to make the distance between

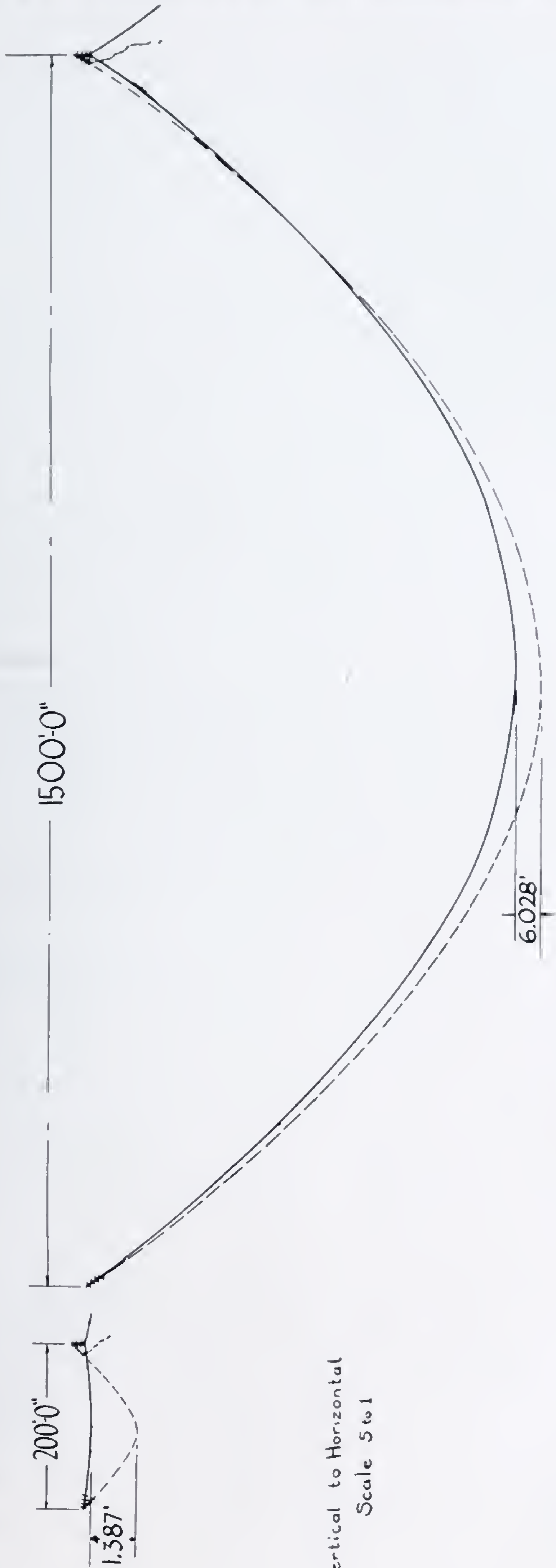

Fig. 5. Diagram Showing Reduction in Ground Clearance Due to Breaking of Wire in Adjoining Span, for Short and Long Spans.

the connections the same as if the tower were a strain tower. The slight additional cost of extending the peak of the tower will usually be less than the cost of keeping a separate design of tower for this purpose. This system also insures additional clearance between the ground wire and the conductors, which, earlier in this paper, was mentioned as being so desirable.

These remarks will not be so applicable to towers designed for level country, but the writer has found that it would have been a convenience very frequently in the hilly country around Pittsburgh if the towers had been so designed, and he has arranged his latest designs of towers in this way.

After having arranged the wires on the towers and spotted the towers along the line at the most advantageous locations and taken care of clearances correctly, all this care may go for nought if the clamps by which the wire is secured in place are not reliable.

There are many types of clamps on the market, each having its good and bad points. None of these will be mentioned or directly criticized or commended by name. It is the writer's purpose simply to enunciate certain principles which must be followed to secure an ideal clamp, and allow anyone to decide from these principles whether or not a clamp offered to him is a good clamp.

The first principle is that a clamp should grip the wire firmly without injuring it. The first requisite to this is that the wire should not be bent until sufficient friction has been applied to develop a gripping power equal to the weakening action of the bend. There is one clamp on the market which has a very well shaped groove for gripping the wire, and in tests, as far as the writer knows, it always breaks the wire before any slipping is apparent; but the wire is bent on entering the clamp and always breaks on the outside of the bend and at a lower tension than the expected strength of the wire. The writer would not consider this an ideal clamp.

While it is desirable that the gripping surfaces of the grooves in the clamps be serrated to increase the friction, yet these serrations should not be extended to the end of the clamp, but the groove should be smooth for a certain distance from the end to allow the wire to receive sufficient frictional contact to make up for the decrease in strength caused by the biting in of the serrations. The arrangement for applying pressure should be such as to insure pressure on

this smooth portion of the groove. After sufficient friction has been applied to take up part of the strength of the wire, the binding action of the clamp may be applied in any way which will secure the maximum gripping power. A clamp, to be ideal, should be so arranged as to be easily assembled on the tower; or, if possible, have all parts completely assembled before placing on the tower so that the wire can be slipped in and the clamp tightened without the man having to place portions of the clamp bolts or nuts in place while strapped to the tower and hanging out in an uncomfortable position. Very few clamps, if any, on the market at present, will meet this requirement absolutely. All that are now in use, to the writer's knowledge, require some part or bolt to be placed after the clamp is in position on the tower. The advantage of this point we have mentioned is apparent to any who have attempted to clamp a wire, as the dropping of a bolt or a nut out of a man's hand when he is up on the tower is very irritating, to say the least.

The tightening arrangements on the clamp should be such that the pressure can be applied in the shortest possible time. There is one clamp on the market which requires the man assembling the clamp on the tower to place the under clamp bar in position and then insert six U-bolts and put on 12 nuts and tighten these 12 nuts before wire is clamped—all of which must be done while he is hanging out from the tower in a very uncomfortable position. The assembly of this clamp and the tightening of bolts take nearly half an hour when done on the ground where a man can apply his full strength, so it is apparent that for a man in the position he must take on the tower, the time he must take for tightening the clamp must seem interminable. Such a clamp can not be considered an ideal clamp because a man is tempted to slight the work of tightening up the bolts, allowing the wires to slip and nullifying all the efforts the engineer has put forth to design a good line.

The binding action of the clamp should be such that the tighter the wire is pulled the tighter will it be gripped. The advantage of this is that as the wire is placed under tension it decreases in diameter, and unless such decrease is compensated by a tighter grip of the clamp the wire is apt to slip when under high tension. The clamp should be so arranged that the line of tension will pass directly through the main body of the clamp so as to eliminate any tendency to bend the

clamp. The writer has inspected some clamps in which the line of action has at times been nearly an inch outside of any metal in the clamp. This necessitates extra weight in the clamp to obtain the required strength, thus making the clamp more expensive and more difficult to handle. A strain clamp should have a curved groove on the end nearest the tower to give the jumper wire connecting it with the next clamp sufficient clearance from the cross-arms of the tower to prevent flash over.

A suspension clamp should have sufficient gripping power to prevent the wire slipping in case a wire in an adjoining span is broken, as such slip of the wire makes it difficult to bring the wire back to its proper position and will often damage the wire sufficiently to reduce its strength very materially. If the clamp does not have sufficient gripping power to hold the wire under these conditions it should be so arranged that the wire can be slipped through it without injury and can be brought back to its position with little trouble. The reason for making this statement is that the question of allowing suspension clamps to slip at a certain fixed tension in order to reduce the strain on the towers is being seriously considered by some designers. The final characteristic of an ideal clamp is that it should be light. It is a very serious matter to handle a heavy clamp up on a tower, and any saving in weight will cause the man who is attempting to string the wire to bless the designer.

In connection with the question of clamps, the question of splices will be discussed briefly. In most of the rules for safety of transmission lines there seems to be a prejudice against splices in wires. Constructors of transmission lines are prohibited from placing splices in the span crossing over a railroad, over a river, or over a wire of another company. This rule is a relic of the old days when splices were made by twisting the wires together. With the modern sleeve splices on heavy wires the strength of the splice is as great as that of the wire itself, and if the splice is a well-made sleeve splice there is no real reason for legislating against it, except that an allowance of five per cent. for weakening of wire due to twisting while splicing is advisable.

When wire is to be socketed at the end, if the socket is attached to the wire by means of molten metal poured into the socket, the portion of the metal which is to flow around the wire just as it enters

the socket should have a melting point so low that it will not anneal the wire being socketed. This is important in the case of copper wire, as a hard-drawn wire will quickly become annealed if melted lead or zinc is poured over it. A low-fusion alloy should extend a sufficient distance from the outer end of the socket to give a gripping power equal to the difference between the strength of hard-drawn and soft-drawn copper. After a sufficient amount of tension has been developed, other metal or alloy can be poured in to complete the socketing. If the sockets are placed on by pressure, they should be carefully tested to find their gripping power and never used in any location where they would be subjected to a greater stress than would be safe considering the minimum gripping power which the test shows to be the ultimate strength of the socket.

As to the method of attaching insulators to the tower itself, there are two general types of connections—with a clevis and with a hook. The hook is the least efficient from a mechanical standpoint, but it allows the greater play in the movement of the wire, and for this reason has been able very largely to hold its own against the clevis. The clevis has the advantage of greater structural strength for the same weight; but, as it is usually connected, it allows a very limited play in one direction, which often results in subjecting the clevis to bending, which sometimes distorts it and shears off the cotter usually used to fasten the clevis pin, thus allowing the clevis to fail at less than its supposed ultimate strength. The writer has found that the strength of the clevis is very greatly increased if, instead of fastening the pin in place with a cotter, a threaded bolt is used for the pin and secured in place by a nut. This will take very much higher tension and a larger amount of twisting before the bolt will pull out. When a clevis using a cotter pin is tested, it almost invariably fails by the bending of the pin, which results in shearing of the cotter and allowing the clevis pin to pull out. Clevises made of steel should be thoroughly annealed before being used, and when galvanized they should be allowed to cool slowly instead of being dipped in water after leaving the galvanizing bath. They should then be tested to a tension equal to that which they will receive in actual practice, and to this test there should be added a shock test. The writer will here give the test which he usually requires of clevises intended for use in transmission lines.

The clevises, after being galvanized, are subjected to a hammer test, being given one sharp blow of a two-pound hammer in such a way as to compress the jaws towards each other. The jaws are then separated with a wedge to their original shape. No cracks must develop under this test. The clevises are then strung up in chains of twenty or more to a chain and tested with a load at least 10 per cent. greater than the maximum load ever expected in the field. This is usually done by lifting a pile of steel equal in weight to the specified load with a crane, inserting chains of clevises between the hook of the crane and the load. While this load is in suspension, the chain is struck three heavy blows with a crowbar. The clevises are then taken apart and each one tapped to see if it will give out a clear ringing sound.

Considerable trouble was experienced from breaking of clevises before this procedure was adopted, but since its adoption no clevises which have passed this series of tests have broken in the field.

The insulators should be thoroughly tested and reliable before being accepted for use on any line.

The manner of connecting ground wire to a tower has usually been by means of special ground-wire clamps, which are either pressed steel plates or grooved castings arranged to grip the wire and usually to bend it at the same time. Considerable trouble has been experienced with this type of clamp because it allows no freedom of motion to the wire without bending it. The wire is almost invariably bent as it leaves the clamp, and as it swings in the wind it is continually working back and forth at the clamp, which results in weakening the wire and in eventually breaking it at that point. The company with which the writer is connected has been removing all ground-wire clamps from its towers and substituting a connection similar to the strain connection for conductor wires, except that no insulators are placed between the hook or clevis and the clamp. It is believed that this procedure will eliminate the trouble formerly experienced from the wearing out of ground wires at the clamp.

Passing now to the question of foundations, we find that there is still much difference of opinion. In this discussion they may be classified in two general divisions — pole foundations and tower foundations.

The first of these divisions consists of foundations in which compressive or uplifting stresses are of little importance, the main point being the resisting power of the foundation to a lateral pull on the pole.

With regard to wood poles, practice has been pretty generally standardized, and the depth to which any length of pole must be set in the ground has been established by experience.

The writer has found it to be a matter of wonder and doubt in some cases as to why the engineer in designing foundations for steel poles requires such large blocks of concrete to be placed in the ground, while wood poles are set in place without any concrete and yet hold up.

The reason for this is that a steel pole may be designed to meet any strength requirements and it is possible that the steel pole is as much as 10 times as strong as the wood pole which the objector has in mind. It is apparent from this fact that a footing which would develop the full strength of the wood pole would be entirely inadequate for the steel pole.

The method which the writer uses for determining the size of footings to be used is as follows:

The upper foot of earth at the surface is neglected and considered as having no value in resisting the overturning moment. The reason for this is apparent, as surface earth has very little resisting power during wet and thawing weather. The resisting moment of the rest of the footing is determined by finding the section modulus of the vertical surface of the footing and multiplying that by the bearing value of the soil. For example, let us assume a pole carrying a total horizontal load of 10,000 pounds, due to the tension in and wind pressure on the wires, the center of gravity of this load being 35 feet above the surface of the ground, and the safe bearing value of the soil being taken at 5000 pounds per square foot.

Let x = breadth of the foundation, in feet, and y = depth of the foundation below the ground line, in feet.

The distance from the center of the load to the center of the resisting portion will then be $35 + \left[\frac{y+1}{2}\right]$ and the moment about this center will be $(10{,}000)\left[35.5 + \frac{y}{2}\right] = 355{,}000 + 5000y$ foot-pounds.

The resisting moment will be

$$\frac{x\ (y - 1)^2}{6}\,[5000] = (xy^2 - 2xy + x)\left[\frac{5000}{6}\right].$$

Then, since the overturning and resisting moments must be equal, we have $(xy^2 - 2xy + x)\left[\frac{5000}{6}\right] = 355{,}000 + 5000y$, and clearing, we get, $xy^2 - 2xy + x = 426 + 6y$. Since this equation has two unknowns, and there is no minimum value, it is necessary to select a value for one of the unknowns and determine the corresponding value of the other quantity. See Fig. 6.

In this case let us assume a value of 11 feet as the depth to which we can go; or, in other words, $y = 11$. Then from the equation we get $x = 4.92$ feet, or we will say 5 feet. This fixes the size of the footing to resist this moment, in a soil which can be depended on for a resistance of 5000 pounds per square foot, as five feet square and 11 feet deep.

This method neglects the friction of the earth on the other faces of the pier, but to offset this we have the fact that the earth placed in compression near the top of the footing has only the weight of one foot of soil to hold it in place and help its bearing power, so that it would appear that this method will give about as nearly correct results as can be obtained by any method except actual test.

The writer has also used this method for heavy anchorages to hold guy cables, where very heavy stresses are involved. None of these has failed or shown any sign of weakness, so far; and, as some of these anchors have sustained unexpectedly heavy stresses, the writer feels justified in placing the above method before the engineering profession.

The second division in our classification of foundations is that of tower foundations. This division is separated into two classes—compression, and tension or uplift foundations. Besides these we have a special class which must sometimes be used—that is, foundations standing on ground which is below high-water line of a river or large creek.

Piers for the two regular divisions are often made interchangeable, as it is very often necessary to have the tower arranged to take possible stresses in either direction, such as a suspension tower in a

line, or an anchor tower which is placed in the line at every mile to provide safety in case of a serious breakdown of the wires, and in a number of other instances where a pier may be called upon to take either compression or uplift.

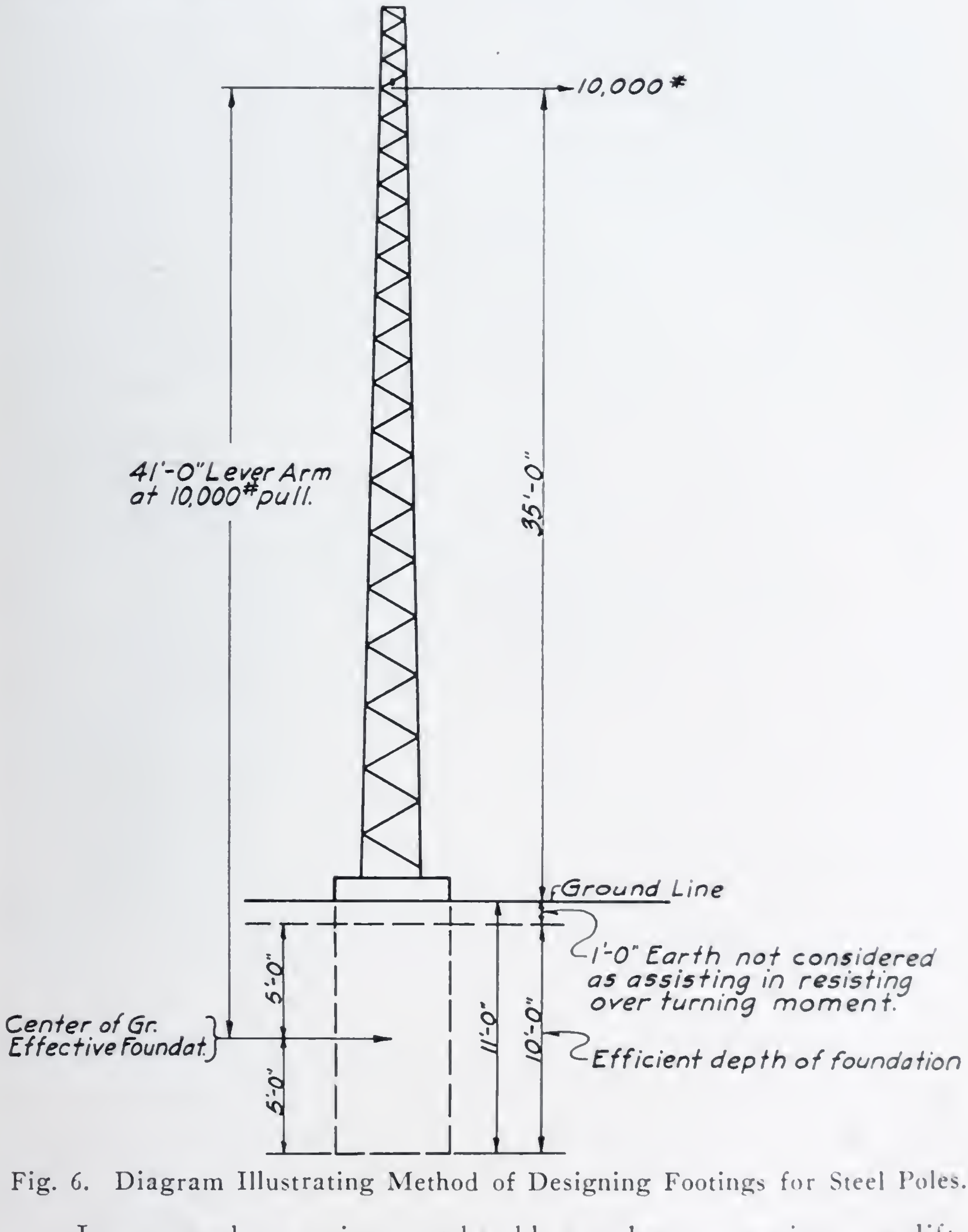

Fig. 6. Diagram Illustrating Method of Designing Footings for Steel Poles.

In a case where a pier must be able to take compression or uplift, it is usually found that if it is designed to resist the uplift it will withstand the compression. For that reason it is the general practice to consider the uplifting stresses only, except where the compressive

stresses which it must withstand at times are so much higher than the uplifting stresses that they must be considered the dominating factor in the design.

Besides these two direct stresses, the piers must transmit the shear from the tower to the ground. Where concrete footings are used, these stresses are so slight that they are usually negligible—that is, if the other stresses have been provided for, the shear is automatically taken care of unless the surface soil is of very poor quality. Where the steel anchors are buried in the earth, however, and there is nothing but a single, angle-iron extension to the post of the tower in the ground to transmit the shear to the earth, the yielding of the small resisting surface to the pressure of this post may tend to distort the tower in such a manner as to affect the distribution of stresses or to cause a bending moment in the post. The provision for these stresses will be taken up in regular order.

The first type of stress is compression. The same general methods are used in designing piers to take these stresses as are used in ordinary engineering; except that a modification of procedure may be used to economize material, due to the fact that maximum stresses rarely occur, and then only for short periods. There are other stresses which occur more frequently and for longer periods of time. Then there are the stresses which recur still more requently. The writer's practice is to design the footing to take the frequent stresses in the same manner that he would for any other engineering project. The results are then checked up with the occasional stressses with an allowance of 33 per cent. excess in unit pressure, and again checked against the rare stresses with an allowance of 50 per cent. excess in unit pressure. Later in this paper is given a table of bearing powers of different soils.

In designing standard piers for a transmission line, the nature of the soil can not be predetermined except in rare instances, so an assumption has to be made to furnish a basis of design. In this case the writer assumes that the soil is such that a load of two tons per square foot can be safely placed on it in general practice. If poor soil is struck at any tower, the matter should be reported by the inspector in charge of construction and a special pier designed for that location. The assumption as to the bearing power of the soil must be left to the

judgment of the engineer, after the general character of the land over which the line is to be built has been determined.

Where the footing is a steel grillage, the total area covered by the grillage may be taken as the bearing area of the footing, since the pressure will distribute itself over the whole area if the bars or other members in the grillage are spaced closely enough. These bars or beams should not be spaced farther than one foot apart. The writer does not favor the method of placing an angle around the edges of the surface covered by the footing and leaving the entire internal portion of the area to receive its pressure from earth distribution. See Fig. 7.

The general rule followed in designing footings to resist uplift is to consider the weight of a volume of earth covering the footing at its base and spreading out in all directions from the base at an angle of 30 degrees to the vertical and extending to the surface of the ground.

The formula for this, if the footing is square, is as follows:

Let b = one side of the base.
d = depth of base below surface of the ground.
w = weight of cubic unit of earth.
R = resistance of footing to uplift.

Then we have,

$$R = w\left[b^2d + 2bd^2\sqrt{\frac{1}{3}} + \frac{\pi d^3}{9} \right].$$

If the footing is circular, and b = the diameter of the base, other letters retaining their significance, we have,

$$R = w\left[\frac{\pi b^2 d}{4} + \frac{\pi b d^2}{2\sqrt{3}} + \frac{\pi d^3}{9} \right].$$

If the footing is rectangular with sides b and c, we have,

$$R = w\left[bcd + (b + c)d^2\sqrt{\frac{1}{3}} + \frac{\pi d^3}{9} \right].$$

$$\sqrt{\frac{1}{3}} = 0.57735 = \tan 30 \text{ degrees.}$$

$$\sqrt{3} = 1.73205 = \cot 30 \text{ degrees.}$$

When a concrete pier is included in the footing, the weight of the portion of concrete below the surface exerting the uplift pressure on the earth must be included; also the weight of the concrete above

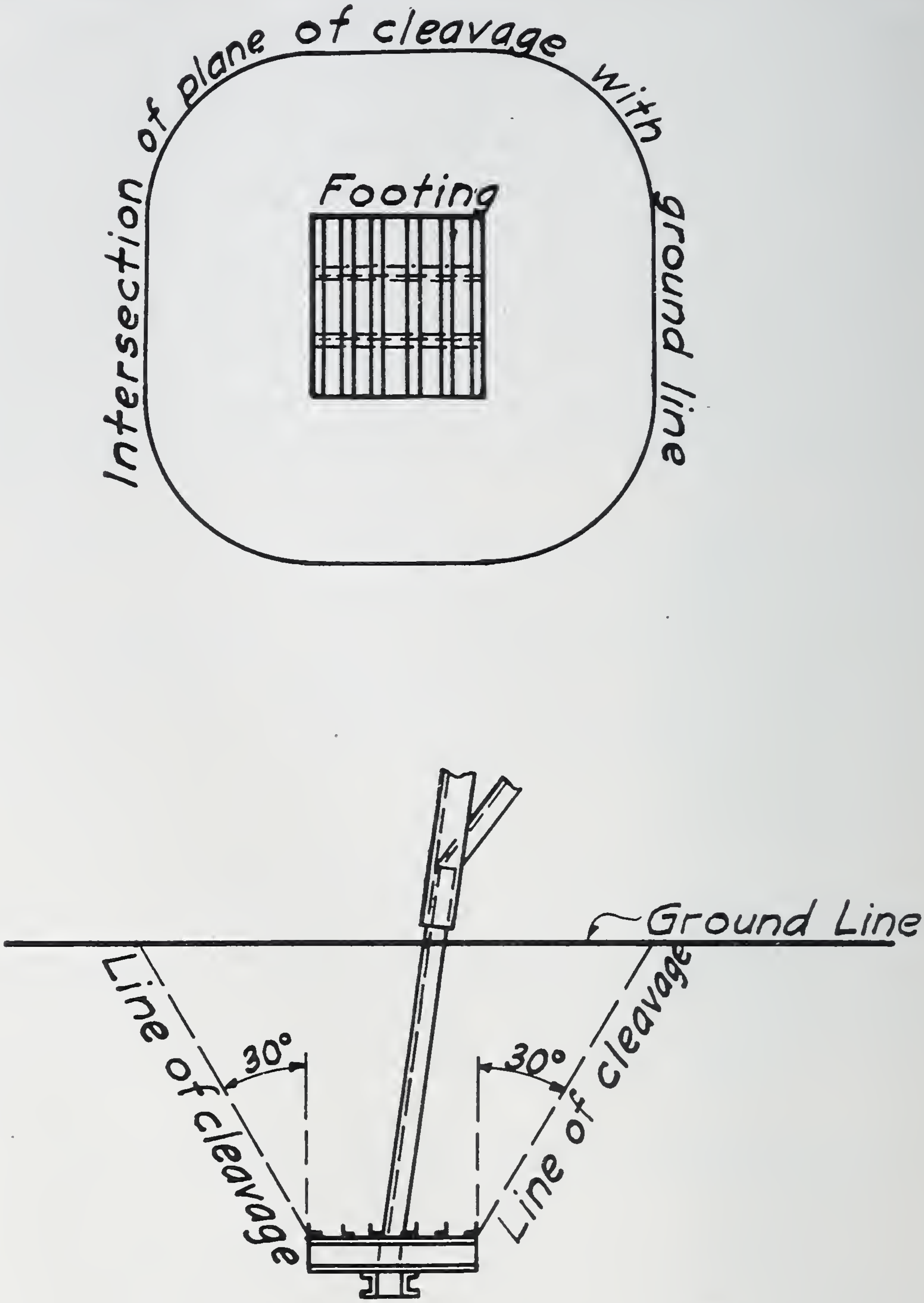

Fig. 7. Diagram Showing Method of Determining Resistance to Uplift of Steel Anchors for Towers.

ground. The volume of concrete which is included in the space taken in by the above formulæ must be taken at the difference in weight

between concrete and earth, since the application of the formula gives the weight of all the earth exerting resistance to uplift, and if part of this earth is replaced by concrete weighing more per cubic unit, we have increased the resisting power of the pier by this difference in weight. For example, let us take a pier with a footing five feet square and one foot thick, the top of this footing being six feet below the surface of the ground. On this footing course is a frustum of a pyramid, four feet square at the base and two feet square at the top, which is two feet above the surface of the ground. To find the resistance to uplift given by this pier (taking 140 pounds per cubic foot as the weight of concrete and 90 pounds per cubic foot for earth, which are the unit weights used by the writer in his general practice) we have:

Weight of concrete in footing, 25 cubic feet at 140 pounds	=	3,500
Weight of concrete above ground, 10.167 cubic feet at 140 pounds	=	1,423
Weight of concrete in space included in formula for volume of earth, 64.5 cubic feet at (140 — 90)	=	3,225
Weight of earth by formula ($b = 5$, $d = 6$, $w = 90$)	=	38,992
Total resistance to uplift	=	47,140 pounds.

Fig. 8 shows method of determining resistance to uplift of concrete footings for towers.

The question as to the factor of safety to use in connection with these formulæ is one on which all do not agree. The factor of safety is to a large degree a factor of ignorance. If we knew exactly how much stress a certain member in a structure would stand without injury and knew exactly the maximum stress which would ever come upon it, we would not have to give it any factor of safety. In calculating the required resistance to uplift in footings, some engineers require a factor of three. Why should they? If the loads which will come on the tower are known, and these can be reasonably well determined, the weight of the footing can also be determined within a reasonable degree of accuracy. Why then place three

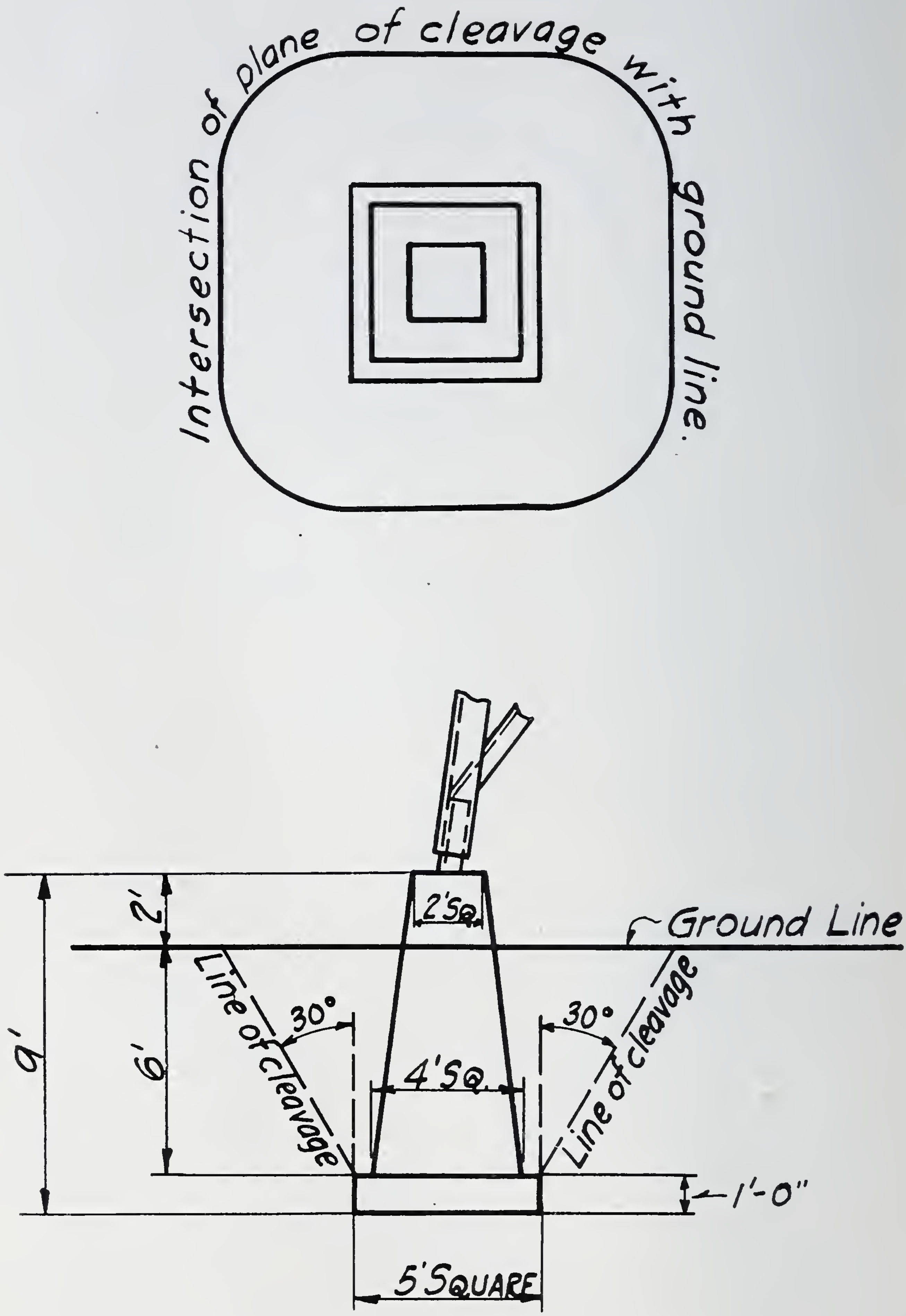

Fig. 8. Diagram Showing Method of Determining Resistance to Uplift of Concrete Footings for Towers.

pounds of weight to resist one pound of uplift? If you wish to lift 100 pounds and exert a force of 99 pounds, the weight will not budge from the floor. Since it is only necessary to have a weight a little greater than the uplifting force, there is no need for a large factor of safety. The writer's practice is to make the effective weight of the foundations 33 per cent. greater than the greatest uplifting force which can be exerted. Some variation in this percentage can be allowed, depending on the conditions of the location, soil and other factors which arise in designing foundations. See Fig. 9.

The tendency for the foundation to become displaced, thus producing a distortion in the tower, can usually be neglected in the case of concrete foundations, as the area presented by these footings to resist this displacement is nearly always sufficient to hold them in place. In case of doubt this should be checked and, if necessary, additional area should be added to the section of the footing to make sure that provision is made for these stresses.

In the case of steel grillages in earth, as we have mentioned before, the matter is not so simple. The post angle of the anchorage is very rarely over six inches wide and often not more than five, which does not present a very large area to take shear, and in cases of extreme stress the angles will cut their way through the ground, especially if the earth is rather soft, thus distorting the tower and causing stresses which were not considered in the design. There are several methods of overcoming this weakness. Some methods consist of placing channels or other sections a short distance below the surface of the ground to present a larger resisting area. Another notable method is known as the Leeper patent, in which the diagonals of the lower panel of the tower are carried down and joined to the post below the ground line. Another method is to divide the main post of the anchor stub into three or four branches, spreading these out in such a way that shear in any direction is taken by one or two of these posts in direct tension or compression. The writer is not making any recommendation of any of these types over another except to say that when earth anchorages are used some means should be provided to overcome the tendency of the anchor to pull through the ground. This trouble could very largely be eliminated by placing a horizontal strut just above the ground line around the tower. This would distribute the load more evenly among the four posts, but at the same

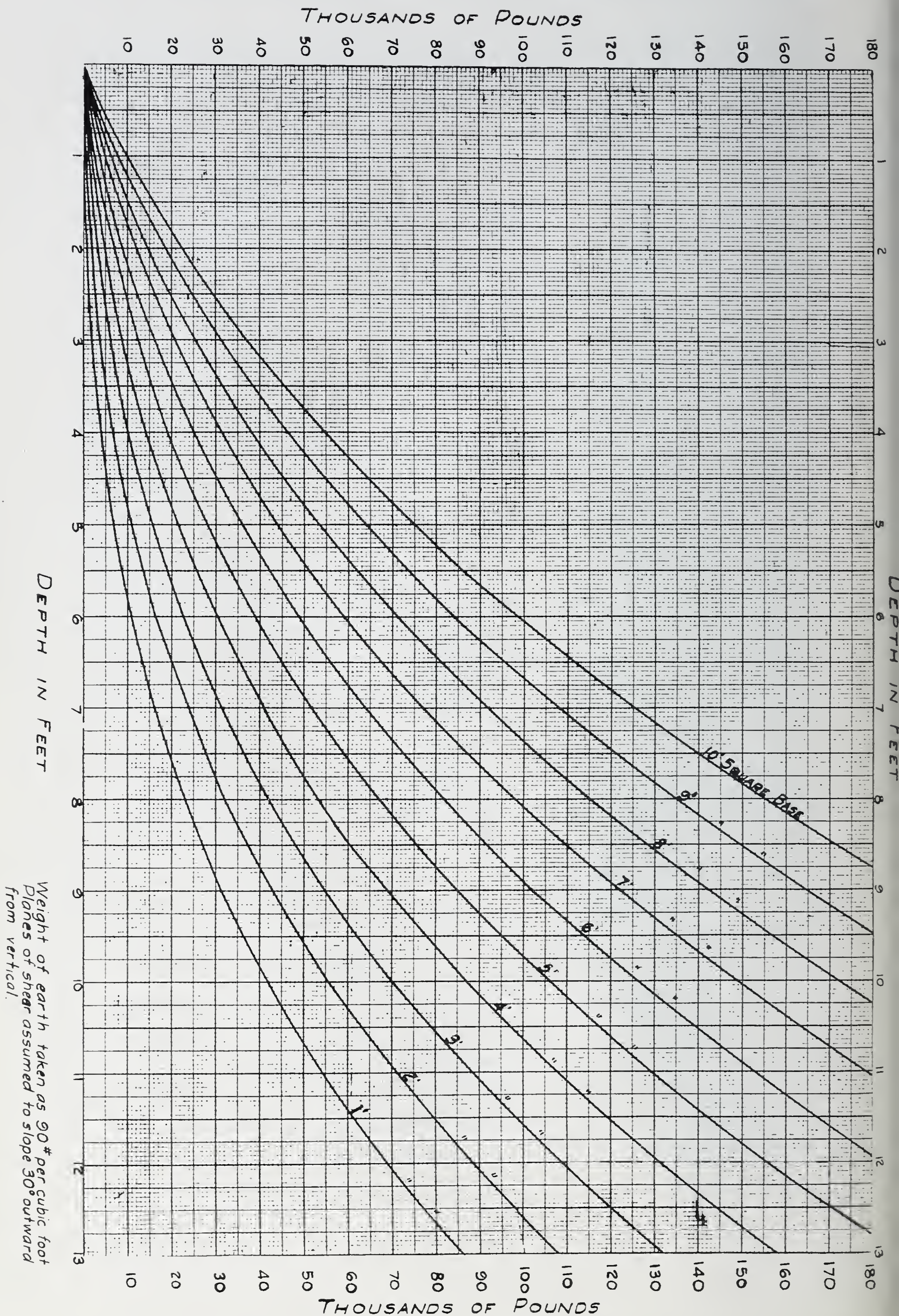

Fig. 9. Ultimate Resistance to Uplift of Transmission-Tower Anchorage.

time it adds considerably to the weight of steel in the tower. The writer's preference when heavy stresses are encountered is to use a concrete anchorage in some form.

Where piers are to be placed in the ground beside a river or large creek, below the high-water line, the problem is very much more complicated. In this case the designer does not figure his foundations simply to take the stress from the tower, but he must take care of floating logs, trees and other debris, and if it is next to a navigable river he must consider the possibility of a runaway barge in time of high water. Piers to withstand these stresses must be very large and thoroughly reinforced. The tops must be braced together and a nosing placed on the upstream side of the pier to relieve the current pressure and to tend to deflect any debris floating down against it.

One other type of anchor will be mentioned, a type which has been patented by Mr. A. W. Malone. The construction of this anchor consists of boring a hole in the ground to a predetermined depth and lowering into that hole a quantity of dynamite with wires and cap attached, placing some earth in the top of the hole, tamping it slightly, and then exploding the dynamite. This compresses the earth at the bottom of the hole, and produces an enlargement of the hole approximately spherical in shape. An anchor post is now set in the hole, the bottom of this post being deformed so as to grip the concrete. The hole is then filled with concrete grout. Numerous tests have been made on this type of anchor, and, when limited to stresses which are within the range of safety as shown by the tests, the writer sees no reason why this anchor should not prove satisfactory.

As to the excavation for foundations, most of this work is done by hand, but there are now some earth-boring machines on the market which should reduce the cost of transmission lines very materially when they are perfected so as to be thoroughly reliable and efficient. The writer has seen one of these machines in operation, boring through very hard clay at the rate of about a foot a minute. The same machine on the previous day had gone through some very hard material which was almost of the consistency of shale rock. These machines are made so that they can be adjusted for position and direction, and can be used to bore the holes for four anchors of a tower with one setting of the machine. The holes can be made large

enough to accommodate earth anchorages for almost any type of transmission tower, or, if necessary, the hole could be widened out slightly at the bottom to accommodate a larger grillage, since the machine is capable of boring a hole large enough to allow workmen to descend into it and shape out the bottom. Of course, there are many places where these machines could not be used, and no machine yet designed seems to be able to operate in ground containing large loose stones, but the writer believes that considerably more than half the tower locations would be within easy reach of one of these machines, and when the designers have overcome certain defects of operation and the machines have come into general use, he believes that there will be considerable reduction in the cost of setting anchors for towers.

Passing on to the question of structures, the writer has already presented a rather extended discussion in which the question of structures has been considered (PROCEEDINGS of this Society, October, 1922). The present paper will present a few thoughts along a different line as the results of more mature study of the question.

We present below a suggested specification for structural steel design. In the matter of loadings and assumed unit stresses, we have taken into consideration the fact that steel will stand an occasional stress far above that which it will stand when stress is frequently applied. We have classified these loadings as, Class A, those conditions which occur rather frequently; Class B, those which occur rarely; and Class C, those which will not probably occur more than once or twice in the period during which a tower is in use.

In this specification also we have tried to rationalize the rule limiting the value of $\frac{L}{R}$ for compression members. In the example given in the foot-note to the specification on slenderness ratio, it is ridiculous to assert that the insertion of a web plate in the column mentioned would weaken the column, yet that is the position taken by many strict literalists in interpreting specifications.

In this specification we have also banned material less than 3/16 inch thick. This point will cause much disagreement. The writer realizes that many lines are in operation where ⅛-inch metal is used in tower members, but his experience leads him to believe that this practice is liable to lead to dangerous breakdowns at critical times, and that all the money that is saved can be quickly dissipated in one

serious breakdown. Our experience has been that metal ⅛-inch thick is not rigid enough to hold its position when the member is under stress. The condition of an angle ⅛ inch thick after being under stress reminds the writer of a folded piece of paper which has been slightly crumpled in a person's hand. With towers spaced so as to give maximum spans, the amount of steel added by raising the thickness of the minor members to 3/16 inch amounts to a very small percentage in the cost of a line. For these reasons the writer believes that the use of ⅛-inch metal in towers is doubtful economy.

At this point the writer submits his suggested specifications for steelwork.

Structural Steel. Structural steel for towers or poles shall be medium steel, preferably that manufactured by the open-hearth process, conforming to specifications of the American Society for Testing Materials for this grade of steel.

Thickness of Steel. Thickness of steel shall not be less than the following:

Tower legs: Galvanized, ¼ inch thick; painted, 5/16 inch thick.

Other members: Galvanized, 3/16 inch thick; painted, ¼ inch thick.

Ratio of Slenderness. Unsupported length of tower legs shall not exceed 150 times the least radius of gyration. Unsupported lengths of secondary compression members carrying figured stresses shall not exceed 200 radii, and secondary members carrying unfigured stress shall not exceed 220 radii. Members used to divide unsupported length of compression members shall be strong enough to sustain a thrust or pull equal to a load which would produce a bending stress in the compression member equal to the difference in the allowed unit stress in the compression member for the divided and undivided length.*

*In construing this rule on ratio of slenderness, it should be remembered that the whole is stronger than any of its parts, and, if an assumed removal of a portion of the metal near the center of gravity would leave a section capable of sustaining the load, the value of L/R being within the prescribed limits, the entire section shall be considered as being acceptable, provided that the portion assumed as removed is not counted on as adding any strength to the member.

For example, if a post with an unsupported length of 24 feet must sustain a load of 60,000 pounds, and a section composed of four angles 4 by 3 by ⅜ inches and one web-plate 8 by ⅜ inches is being considered, we find that $L/R = 169$, which is above the limit for posts. If we consider that the web-plate acts as a substitute for a system of lacing bars and disregard any effect it has on total area or on radius of gyration of the post, we would have $L/R = 150$, and a strength at $18,000 - 76\ L/R$ of 65,500 pounds, and such a post should be considered acceptable.

Unit Stresses in Steel. The following values relate to the three classes of stresses referred to above:

Class A

Tension............................20,000 pounds per square inch on net section
Compression,
18,000 — 76 L/R per square inch for lengths up to 150 R
14,100 — 50 L/R per square inch for lengths over 150 R
Bending ....20,000 pounds per square inch
Shear ....16,000 pounds per square inch
Shear on bolts....................................16,000 pounds per square inch
Bearing on bolts.................................32,000 pounds per square inch

Class B

Tension ....24,000 pounds per square inch
Compression,
22,000 — 92 L/R per square inch for lengths up to 150 R
17,200 — 60 L/R per square inch for lengths over 150 R
Bending ....24,000 pounds per square inch
Shear ....20,000 pounds per square inch
Shear on bolts....................................20,000 pounds per square inch
Bearing on bolts.................................40,000 pounds per square inch

Class C

Tension ....27,000 pounds per square inch
Compression,
27,000 — 115 L/R per square inch for lengths up to 150 R
21,000 — 75 L/R per square inch for lengths over 150 R
Bending ....27,000 pounds per square inch
Shear ....27,000 pounds per square inch
Shear on bolts....................................27,000 pounds per square inch
Bearing on bolts.................................54,000 pounds per square inch

Class A shall apply to all stresses produced by the following loading conditions:

1. Purely dead-end towers with no wires in adjacent spans for following loading on wires.

   a. Wires loaded with 0.5-inch coating of ice at 20 degrees F. but no wind.

b. Wires without ice load but sustaining a wind pressure of 20 pounds per square foot on projected area at 20 degrees F. Tower sustaining a wind load of 30 pounds per square foot.

2. Angle towers.

a. Tension on tower due to turn in line, wires considered loaded with 0.5-inch coating of ice at 20 degrees F. but no wind.

b. Tension on towers due to turn in line, wires sustaining a wind pressure of 20 pounds per square foot on projected area at 20 degrees F., no ice load on wires or tower. Tower sustaining a wind load of 30 pounds per square foot.

3. Suspension towers.

Wind pressure on wires, 20 pounds per square foot on projected area at 20 degrees F., no ice load on wires or tower. Tower sustaining a wind load of 30 pounds per square foot.

4. All cross-arms for supporting wires.

Wires shall be considered as stressed to maximum tension and 100 per cent. impact added to allow for sudden application of load due to breaking of wire in adjoining span.

Class B shall apply to all stresses produced by the following conditions:

1. Dead-end and angle towers.

Tension due to dead-ending wires or to turn in the line, wires considered as loaded with 0.5-inch coating of ice, and sustaining a wind pressure at eight pounds per square foot on projected area at zero F. Wind on tower, 13 pounds per square foot. Tower members considered as being covered with ice 0.5 inch thick.

Class C shall apply to all stresses produced by any bending or torsion in tower due to the same wire loading as specified for Class B, but with the following specified number of wires considered as broken:

For towers carrying from 2 to 10 wires, consider any two wires as broken.

For towers carrying from 11 to 16 wires, consider any three wires as broken.

For towers carrying more than 16 wires, consider any four wires as broken.

Foundations. Foundations designed to carry compression stresses shall be so designed that unit loading on soil as specified below shall not be exceeded.

	Class A	Class B	Class C
	—— Tons per square foot ——		
Hard rock on natural bed........	280	375	420
Ledge rock	40	54	60
Hard-pan	9	12	13.5
Gravel	5.5	7.5	8.5
Clean sand	4.5	6	6.8
Dry clay	3.4	4.5	5
Wet clay	2.2	3	3.4
Loam	1.1	1.5	1.7

Footings to resist uplifting stresses shall be designed to have a weight 33 1/3 per cent. greater than the maximum uplifting stresses coming on such footings. For resisting uplift, the weight of stone or gravel concrete shall be considered as 140 pounds per cubic foot, and the weight of earth as 90 pounds per cubic foot. The plane of rupture in earth-resisting uplift shall be considered as sloping at an angle of 30 degrees outward from the vertical.

The question of protective coatings has previously been discussed by the writer, and we shall give no extensive discussion at this time. Since the writer's last article, however, certain defects in the protective efficiency of galvanizing for steel have shown up. In the Pittsburgh district where towers are subjected to smoke, the sulphur fumes in the air apparently react with the zinc coating to form a soluble salt which washes off in the rain and allows the steel to be exposed in a short time, and it often seems that the time required to remove the zinc coating is not as long as that required to remove a paint protection.

At this point we shall diverge from our main subject a little to take up the question of outdoor substation structures, since the transmission line generally ends in such a structure.

There are two general methods of bringing a transmission line into a substation structure. One is to place a dead-end transmission tower at or near the station, allowing the wires to drop from the tower into the station, using a spreading frame whenever the tower is too close to the substation to allow the wires to spread out to their positions in the substation and still maintain their proper clearances at all points. The other method is to extend the substation frame upward until it takes the place of a tower. While this takes more steel for the substation framework, it very frequently results in a more economical construction than the other method.

The older types of outdoor substations were fearfully and wonderfully constructed. The supporting columns and all horizontal members were made of four corner angles laced on four sides, which made a very massive looking structure, involving a lot of shop work and an interminable amount of field work. The tendency at the present time is away from such construction to simpler forms of fabrication. The laced sections or columns are being replaced very largely by H-sections, or if H-sections cannot be economically used an A-frame section of two channels laced together, the strength in the other direction being taken care of by lateral braces. For small installations it sometimes happens that single angle members throughout the station can be used to take all the stresses. When they pass beyond this, H-sections can be substituted. Sometimes two channels in a T-section or a channel and beam in a T-section are used, but in cases where the bus wires produce a greater horizontal bending moment than the vertical, the writer has found that the most useful section is that of a channel and two angles, as shown in Fig. 10, where the design shown below is preferable. The properties of a number of these sections have been worked out so that it is possible to select the section best suited to the needs. There are some objections to this section, but the writer has failed to find any section which answers the purpose as well except an inverted channel section composed of one plate and two bulb angles. While this section is theoretically better than the one we have mentioned, it is so rarely that bulb angles can be obtained when wanted, that we have abandoned even placing the bulb-angle sections on our drawings as an alternative.

As to the method of design of substations, we do not advise that much dependence be placed on charts giving the sag to be allowed in

the bus wires, for the reason that the spans are so short that the wires can not be hooked up in the methods ordinarily used on transmission lines, where there is enough play in the wire to allow it to be drawn up and clamped in place with its proper sag provided for. In the short spans which we find in the substations, connections must be made adjustable in order to allow the workmen to pull the wire up to a reasonable tension. The result of this is that when a workman gets up there with a wrench to tighten the wire, he forgets his sag chart, and is apt to tighten away until he has the wire as tight as he

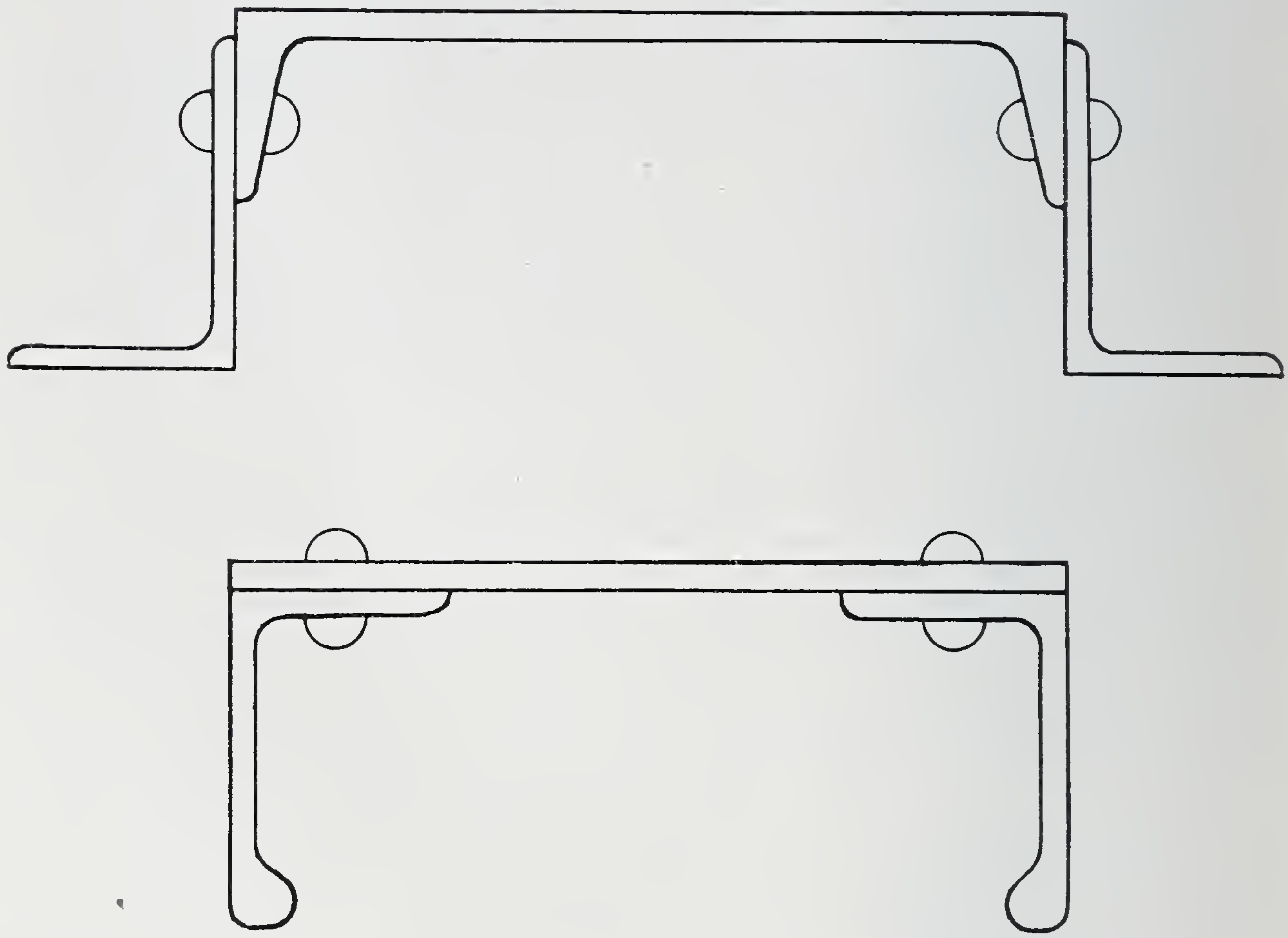

Fig. 10. Sections for Horizontal Strain Members for Outdoor Substations.

can pull it. As the correct sag in these wires is so slight, it is very easy for the wire to be pulled up to where tension would be six times as great as the calculated tension, and it would not be possible to notice it by casual inspection from the ground. The result of this has been rather serious in the writer's experience, and it has led him to adopt the rule that the steel framework of the substation must be sufficiently strong to break the wire before the steel will give way. In designing a substation, then, the writer takes all the bus wires inside the station and assumes them to be stressed to their ultimate tensile strength. Against this he allows in the supporting members, 32,000

pounds per square inch for direct bending stresses, or 40,000 pounds per square inch for a combination of horizontal and vertical bending stresses. This would enable the steel to break the wires, and the writer believes this to be amply safe, since it is hardly possible that all wires will be stressed to their ultimate strength at the same time. In the last few years for shorter bus-bars, copper tubing has come to be used to a large extent. This releases a great deal of the internal stress in the substation, and leaves only the wind- and snow-load stresses to be provided for.

Whenever the station is small enough to allow struts to be placed between the bus supports so as to make the whole frame self contained in the form of a harp, it relieves any stresses in the posts due to the tension in the wires, and reduces the section of the posts very materially.

In this paper the writer has endeavored to outline briefly a few facts which should be recognized by all transmission-line engineers. It is his earnest desire that the engineering profession and all who are connected with the construction and maintenance of transmission lines should break away from the old-fashioned idea of designing this work from cut-and-dried empirical formulæ, and reduce the whole system of design to methods which have a solid basis in scientific fact; and, if this paper succeeds in bringing these principles to the attention of engineers, the writer will feel well repaid for the effort he has put forth in preparing it.

DISCUSSION

E. V. Braden, *Chairman*:* Mr. Martin's natural bent for accuracy, scientific accuracy, in spite of the mass of work involved, together with his experience in this construction and design, make his experience very valuable to the engineering profession, and, personally, I congratulate you, Mr. Martin, on your paper this evening, because I know that it was prepared for this date, which is away in advance of that for which it was originally intended. Two other papers which were scheduled ahead of this could not be produced because of circumstances out of the control of the authors. So, Mr.

*Chief Engineer, Pittsburgh, Chartiers & Youghiogheny Railway Co., Pittsburgh.

Martin, you are to be congratulated on such a good paper on such short notice.

The subject is now open for discussion.

Mr. Martin, you said that the Public Service Commission's General Order No. 13 is being revised, as I understand?

JAMES S. MARTIN: They are working now on the revision of it.

E. V. BRADEN, *Chairman*: And have they had the benefit of your observations?

JAMES S. MARTIN: Yes. I have made suggestions to most of the Committee as to some of these points. I have not had a chance to present my views on all of them.

E. V. BRADEN, *Chairman*: I hope you will have, because some of them ought to be well taken.

S. N. WATT:* As a safety measure I believe that steel poles or towers set in concrete foundations should be provided with a grounding device. Lack of this has sometimes resulted in unpleasant or even dangerous results to passersby.

Mr. Martin's remarks on outdoor substations are very interesting. I believe with him that it is better and more economical to anchor the transmission cables to an independent structure rather than to the substation itself.

As regards the design of structural members of an outdoor substation, it seems to me that latticed columns and girders are preferable to built-up sections. Girders of the latticed type are well adapted to resist torsional stresses caused by eccentric loading from heavy switches or from bus-bars, and will allow more latitude in arrangement of equipment. Latticed columns may be spaced considerable distances apart and do not usually require diagonal bracing, thus freeing the ground area for the electrical apparatus.

JAMES S. MARTIN: We do use the laced members wherever stresses occur that require something heavier than the solid structure,

*Designing Engineer, American Bridge Co., Pittsburgh.

but we break away from them just as much as we can; and wherever we can use a solid section safely we do it. We have found that it has saved us money in construction and in the upkeep of structures.

R. R. SUTTON:* There is one question I would like to ask you, Mr. Martin. In determining your uplift for your piers, you say you add 33 per cent. to your maximum. What do you consider in your design; do you consider the maximum tension that you would figure with your wires loaded, or do you figure the ultimate tensile strength of those conductors?

JAMES S. MARTIN: We take the combination of broken wires, wind loads, angles in the line, etc., that will give what we believe to be the maximum uplift the tower leg will ever get. We do not take that at the ultimate strength of the wires, but we do allow for some overload on the wires in making our computations. The amount of overload will vary with the size of the wire. The writer would say that he believes 25 per cent. for wires ½ inch in diameter, and about 50 per cent. for those ⅜ inch in diameter, will cover overloads in this district.

R. R. SUTTON: I am speaking now of a strictly dead-end of an anchored condition. You say a factor of safety of two is used, or three?

JAMES S. MARTIN: General Order No. 13 requires a factor of three. The writer considers this requirement excessive.

R. R. SUTTON: And do you figure that with relation to the allowable tension in the conductor?

JAMES S. MARTIN: Allowable tension, yes; but since results of overloading on wires will vary so much with size, elasticity, etc., of the wire, and with the length of span, it is our practice to determine the requirements for each important dead-end span separately. On account of the elasticity of the wire, an overload of 50 per cent. will not increase the stress 50 per cent.

*Assistant Construction Engineer, West Penn Power Co., Pittsburgh.

G. E. Flanagan:* I would like to ask Mr. Martin regarding the construction of what he referred to as the copper-covered steel wire. I believe that he spoke of it as welded. I would like a word as to how such wire is manufactured, whether it is really welded or whether the copper is plated on the surface of the steel?

James S. Martin: If it is properly manufactured, there is a weld there. When the heated steel ingot covered with a good flux is placed in the mold and the copper is cast around this ingot a weld is formed so that it is impossible to separate the copper from the steel, while a test of the inner layer of copper will show the presence of iron, and a test of the outer layer of steel will show the presence of copper. When subjected to a corrosion test, if there is simply a contact between the copper and the steel, the copper acts as one of the poles of a galvanic battery and tends to accelerate the corrosion of the steel; but if there is an actual weld, the steel core will pit at the center and corrode very slowly at the outer edge next to the copper, showing that it has become a copper-bearing steel at that point and that there is an actual weld there.

G. E. Flanagan: Do I understand that a combination of a steel center and a copper coating is drawn through dies as in the ordinary wire-making devices?

James S. Martin: Yes, it is rolled out to a 3/8-inch rod and this is drawn through dies in the ordinary drawing process, and it is interesting to note that when it is tested at the end of the drawing process, the proportion between the steel and the copper is practically identical with what it was when cast.

Karl L. Kortlandt:† In connection with these steel-pole foundations that Mr. Martin spoke of, I would like to ask Mr. Martin whether he considers the uniform resisting pressure that he spoke of, to hold for all cases, or whether that pressure is not influenced by the depth of the footing? I have in mind figures given by C. L. Christensen in the *Engineering News-Record* of August, 1924, in which he gives a value of 400 pounds per square foot for the

*Mechanical Engineer, Heyl & Patterson, Inc., Pittsburgh.
†Designing Engineer, Carnegie Steel Co., Duquesne, Pa.

passive resistance of good earth per foot of depth. Recognizing the fact that the top and bottom layers of earth are ineffective in offering resistance to overturning, he assumes a parabolic law of pressure distribution with zero at top and bottom and a maximum at the center of the footing. I would like to get Mr. Martin's views on this method of procedure, if I may.

JAMES S. MARTIN: Theoretically, he may be right, but if you drive a stake into the ground and then try to pull it over, you will find that it resists a great deal more than the results obtained by calculations based on a parabolic formula. In the problem given, the writer simply assumed 5000 pounds as the bearing value of soil for the working of that problem. He would not say that 5000 pounds would be used in anywhere near all cases. In this case it was assumed that ground was a very solid clay. As explained, we throw away the upper foot of soil as far as our calculations go and then count the rest of it as acting. Some of our piers designed in this way have received some very unexpected shocks without showing any signs of failure.

KARL L. KORTLANDT: Do you consider the resisting moment offered by the earth under the base of the pier?

JAMES S. MARTIN: Only the two faces in direct pressure. The resisting moment of the base (unless it is large) and of the friction from the pressure on two sides of the pier are neglected in order to compensate for any lack in resisting power of soil near the surface.

KARL L. KORTLANDT: Yes, but you have also the retaining-wall pressure to consider on the rear surface of the footing.

JAMES S. MARTIN: Yes, we have that.

KARL L. KORTLANDT: Do you consider that 5000 pounds will be accurate for any depth of footing?

JAMES S. MARTIN: Yes, within the limits of ordinary footings. Of course, if the foundation is very deep the bearing value would be

greater, but within the limits of the ordinary pole foundation the writer believes that the use of the bearing value of the soil as a basis for determining resisting moment will result in a safe design.

C. N. HAGGART:* I should like to ask about the foundations for towers and figuring the uplift and the weight of the earth on the posts. Do you reinforce the concrete foundation?

JAMES S. MARTIN: We usually run an anchorage angle down through the pier until it reaches within a few inches of the bottom, so that the pier is reinforced for its entire depth; clip angles are attached to the anchorage angle at the bottom; and only enough concrete to protect the steel is placed between the bottom of the anchorage steel and the bottom of the pier. In this way the steel is made to transmit all the tension.

C. N. HAGGART: In a positive way, of course. I should like to ask, also, if you make any special attempt to protect the metal where you have a steel column going down in the earth?

JAMES S. MARTIN: The anchorage steel is galvanized in all cases of that kind.

C. N. HAGGART: Is that sufficient to protect it for any length of time?

JAMES S. MARTIN: We have had some of them in earth for 10 years, and we have not had any trouble with them yet. Galvanizing will probably last longer in the ground than it does above ground, because you have only the moisture under the ground to contend with and you have no smoke and sulphur fumes. Referring again to reinforcing the piers—in addition to the method previously mentioned, if the pier has to take any special load, or if it is to be subjected to any loads which would not be taken care of by the shearing strength of the concrete, steel rods are used and sometimes a grillage of beams or old rails placed in the footing course.

*Structural Engineer, Pittsburgh.

F. M. McCullough:* I wish to ask the speaker whether he has made load tests on transmission towers in order to check the theoretical stresses by means of measuring the deformation with various members with a Berry strain gage or some similar device?

James S. Martin: You mean tests of different sections, and individual parts of the towers?

F. M. McCullough: Yes, by placing the gage on various members to determine the deformation in those members.

James S. Martin: No, we have made no such tests. We have had some of our towers tested. We have observed them as regards deformation of the towers, but have not had any gage tests taken.

F. M. McCullough: I believe that such an investigation would prove very valuable.

James S. Martin: I should imagine that it it would, if anybody had any opportunity to take it up.

Karl L. Kortlandt: In the case of a heavily loaded tower at the end of a transmission line with all wires leading off into a nearby substation through the base of the tower, the four footings would have to be combined into one chamber or vault like a concrete structure; how would you consider the leg reactions distributed over and transmitted to the soil?

James S. Martin: Are you speaking of a foundation vault?

Karl L. Kortlandt: Making it a closed structure—that is, chamber like in form—it is difficult to segregate the uplifting stresses coming on one part of the structure from the compressive stresses acting on the other part. To my mind the entire footing would be subjected to an overturning moment.

James S. Martin: Yes, it would be in that case. We have never constructed such a footing and have not gone thoroughly into

*Professor of Civil Engineering, Carnegie Institute of Technology, Pittsburgh.

the matter, but the resisting value of a foundation like that would be determined by the stability of the vault.

KARL L. KORTLANDT: Would you separately consider the resistance or pressure from the front and also from the bottom of the footing?

JAMES S. MARTIN: Yes, I think so. Of course, if you had a footing extending beyond the walls of the vault, so as to catch some of the earth, you could depend on the weight of that earth to increase the stability of the foundation.

M. E. NOYES:* I should like to make some very favorable comments on Mr. Martin's paper. Having had some experience with the difficulty of applying rule-of-thumb methods to the determination of clearances above ground and above crossings, I agree that it is very difficult to establish such methods. There is only one theoretically correct method, and that is to specify minimum clearance under maximum sag conditions. The fact that it takes an engineer to apply this method ought to be faced. This question has been discussed with us by some of the members of the various committees now engaged in the revision of the National Electrical Safety Code, and it seems to me that it would be quite desirable for your Society to present these committees with copies of Mr. Martin's paper, thus giving additional weight to opinions already expressed to them. They are in a difficult situation trying to please everyone, and I believe it is desirable to give as much weight as possible to the theoretically correct way of expressing these rules.

Another point in Mr. Martin's paper that interested me, and which I think is an extremely good point, is the matter of proper design of attachments for overhead wires and cables. He particularly mentioned ground wires, and the trouble experienced from attaching these rigidly to the peak of a tower. His solution is undoubtedly good; namely, placing clamps out on the line, thus giving the attachments flexibility with the cable.

I also enjoyed his discussion on the subject of suspension clamps. There is one point which I think might be brought out in this con-

*Sales Engineer, Aluminum Co. of America, Pittsburgh.

nection, and that is the proper radius of curvature of the suspension clamp; not only from the standpoint of the position of the wire when broken on one side, but also from the standpoint of the natural bending of the wire up and down. There is a pretty well developed standard practice in the use of steel haulage ropes, and it is well known that the larger the diameter of the stranded cable, the larger the diameter of the sheave or the drum over which it passes. I might mention here a test recently run by a prominent power company. I do not have full details, but it consisted of passing a large piece of transmission-line cable through an ordinary type of suspension clamp, and supporting from the ends of the cable a loaded frame. The result was that the cable passed through the clamp in approximately the position which would exist on a line, and was subject to a reasonably high tension—something approaching the elastic limit. The clamp was then rocked in such a way as to produce bending of the cable up and down relative to the clamp. In about two minutes, I believe, they broke the strands of the cable several inches outside of the mouth of the suspension clamp. This indicated quite conclusively that for this particular diameter of cable the clamp should have provided support to the cable several inches farther out. I venture to say that proper design of conductor attachments for transmission lines is one of the features of transmission-line engineering which is about to be more carefully considered. It is obviously not correct to use the same radius of curvature in a suspension clamp for wires either ¼ inch in diameter or ¾ inch in diameter, yet this is common practice at the present time.

Mr. Martin made one statement which is not clear to me. In his discussion on materials for overhead ground wires, steel-reinforced aluminum cable was mentioned, and the statement made that aluminum by its very nature was not a suitable material to conduct a lightning charge. Isn't it true that any material would probably be chopped off by a direct stroke? I have had no personal experience in observing this, but have always understood this to be the case.

James S. Martin: Of all the materials used, aluminum is probably the easiest.

M. E. Noyes: It is true that aluminum has the lowest melting

point of any material commonly used as an electrical conductor. The melting point of aluminum is 1217 degrees F.; the melting point of copper, 1982 degrees F.; and the melting point of steel, approximately 2500 degrees F. The temperature of an electric arc is probably in the neighborhood of 8000 degrees F. A difference of 600 or 700 degrees in the melting point of two materials would have very little effect on their relative ability to resist a direct stroke of lightning.

James S. Martin: That is true, but we have had some copper wires that have had a direct stroke and not been burnt off. Our field men report the following observations:

When a copper wire is burnt by lightning the damage is local and only a small portion is injured; but, with aluminum wire, one strand or two will burn off at one point and a few more strands at some other point, scattering the damage over a considerable distance. I do not know of any reason for this, but our men in the field report that they have to face this difficulty when aluminum wire is struck by lightning, making it hard to be sure that all the injured wire is removed.

M. E. Noyes: I think this would be due to the nature of the arc rather than to the character of the material of the conductor.

C. W. Kenney:* I wish to congratulate Mr. Martin on the very able way in which he has handled this subject. The new ideas he has introduced and the new light he has thrown on the older practices of transmission make this paper a valuable contribution to the engineering profession.

I am heartily in accord with Mr. Martin, and the last speaker as well, in regard to wire attachments. The need for more careful consideration of the functions of wire clamping and wire-clamping devices should, I feel, be stressed at this time. In the past it would seem that the whole consideration in designing wire clamps has been aimed at the holding power of the clamp against slipping, disregarding the effect or possible reduction in the strength of the wire itself; and very little, if any, consideration has been given to the tendency of the clamping devices to cause crystallization of the wire at the

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point of attachment. This condition perhaps is found more generally in the method of attaching overhead ground wires than in conductor attachments. In fact, the overhead ground wire in most instances—while installed as a protective device—has become a very frequent source of hazard to the circuits it is supposed to protect, universal practice having been to clamp this wire rigidly to a member of the tower structure so that there is no latitude of oscillation whatever, thus concentrating all vibration or wire movement from wind action at the attachment point. That this condition will eventually produce deterioration of the wire at the attachment point is scarcely debatable, the time when this will occur depending largely on the character of the material of the wire.

Another point brought out by Mr. Martin, which I feel is quite timely, is that of the form of foundations. While we can not say that tower superstructure design is standardized, from the point of view of economical design at least, as well as performance of its intended functions, very satisfactory designs have been achieved. As to the form of foundations, however, I doubt that any engineer is satisfied at the present time with the forms now in use or with the cost of installing foundations. Perhaps it is a natural disinclination to expend so large an amount of money on subsurface structure, but it is my opinion that foundations for steel-tower lines are at the present time costing entirely too great a proportion of the total cost of the transmission lines. I believe there are many engineers who are looking for some change in foundation design that will reduce the cost and still maintain the required strength; and, with the number of engineers interested in and working on this proposition, I should not be surprised to see in the near future, if not a radical change in type, at least a considerable departure from present practice in foundation design for steel towers. Whether this reduction in cost of foundations will be accomplished entirely through modification of design or partly through the development of mechanical equipment for placing foundations, I can not say, but the fact remains that both items are being pretty carefully studied by engineers at the present time.

One of the evidences of the attempts to modify the foundation design is the so-called Malone anchor. The West Penn Power Company has for over 10 years been using a mushroom anchor, produced with dynamite, for tower foundations and also as a foundation for

other structures and machinery foundations. The first towers to be constructed by the West Penn Power Company on this form of mushroom foundation were constructed at Elizabeth, Pa., in 1914. Since that time, many other river-crossing structures and foundations have been constructed by this company in the same way and they have proved very successful, particularly where located on alluvial flats bordering large streams. The method generally used in installing these foundations was by boring with an earth auger to the required depth, placing the dynamite in the bottom of the hole, and dumping the concrete immediately thereon, exploding the dynamite as soon as the bore-hole was filled with concrete, allowing not more than four minutes from the time the first concrete was placed until the dynamite was exploded. Under favorable conditions we were able to secure a displacement in deep holes to a maximum of 1¾ cubic yards, this, however, being considerably above average and in most cases larger than the required size of the mushroom footing. The method of expanding the hole before placing the concrete has also been used, but there are certain advantages in expanding after the concrete is placed, particularly prevention of scabbing of the sides of the holes due to concussion, which does not occur when it is supported by the pressure of plastic concrete. No difficulty is found in removing the gases from below the mass of concrete after the explosion, and in many cases the gas comes out immediately, allowing the concrete to settle in place; but, where this is not the case, the gas can very readily be tapped out by inserting a bar or pipe through the plastic concrete to the gas pockets.

The form of this foundation lends itself to tower work particularly well, as it is equally good for either compression or uplift. This method has been successfully used for foundations for building purposes to a depth of 34 feet below the surface. The size of bore-hole used for this purpose is usually determined by the vertical loading in the case of foundations for buildings; or, in the case of tower foundations, by the horizontal shear at the ground line, in which case it should be large enough to oppose sufficient area against the earth to take care of this shear.

This same item of horizontal shear at the ground line is something which seems to have received rather too little attention from the designers in many types of earth grillage foundations, many de-

signs apparently having an inadequate area of steel opposed to the earth to take care of this horizontal pressure properly. This, of course, is not true of the tripod type of foundation, provided the members of the tripod are calculated to take this additional stress in addition to the uplift or compression applied directly through the tower leg. Where the design depends on shear plates to transmit this pressure to the earth, too little attention seems to be paid to the fact that of necessity the shear plates must bear against the backfill, which can hardly be expected to take more than a very low unit pressure for quite a period after construction.

The West Penn Power Company has one feature in foundation design that I believe is unique; that is, the use of a renewable member connecting the main leg member of the tower to the foundation. This is used with the belief that deterioration of the metal will be most rapid at the ground-line, and the renewable part as used with concrete foundations extends the length required for a joint, plus two inches above the surface of the concrete, and the same distance beneath the surface of the concrete. In the case of earth grillage foundations, this member extends the length required for a joint, plus six inches above the ground-line and 2½ feet below the ground-line, and is so designed that it may be removed and renewed without disturbing any other part of the tower or its foundation.

STEAM RAILWAY ELECTRIFICATION*

By W. B. Spellmire†

INTRODUCTION

The aggregate wealth of the United States is estimated at $340,000,000,000, and of this total about $40,000,000,000 is represented by agriculture. Co-operating actively with agriculture, and during a period of about a century, the railroads have grown to such proportions as to assume second place in magnitude, and represent a capital investment in excess of $20,000,000,000, or near the amount of our present national debt. Through their system of transportation of passengers and freight, they are to a large measure responsible for the greatness of this country to-day. They have joined city to city and state to state. The resulting intercourse has made for unity of understanding of the nation's problems; promoted civilization and the use of a common language; made possible the rapid exchange of commodities; and has been of indispensable value in our national defense. In dwelling on the great achievements of the railroads, much care should be observed to give due credit to the one great dynamic machine which has made them possible. That great machine is the steam locomotive, and all that is said in praise of railroad accomplishments must be extended to the steam locomotive. In our childhood, its very noise symbolized the train. As a moving object, its power and size have always made a tremendous appeal, and its performance has been spectacular—all this aside from its great economic value.

The steam locomotive has a wonderful record to its credit, and in many places will doubtless continue its great work in the future as in the past. The time has come in the march of progress, however, when we must recognize a worthy competitor. Electricity has replaced the steam and mechanical drives formerly applied to cable-cars, inclined planes, elevators, cranes, coal and ore bridges and unloaders, mine hoists, steel-mill drives, battle-ships, passenger and cargo vessels, and in fact practically all applications of power, and is measured by

*Address of retiring President. Presented January 19, 1926. Received for publication March 9, 1926.

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motors varying in size from 1/200 horse-power to more than 20,000 horse-power. In Europe and South America there has been much electrification of railroads. All this being the case, how does it come about that railroads in the United States are not more generally electrified?

On our railroads we have about 65,000 steam locomotives, representing a total of, say, 65,000,000 horse-power capacity available in steam-generated energy. Each one of the 65,000 steam locomotives is in reality a portable, non-condensing power-plant with its small boiler, fire-box, and engine, drawing along behind it in a tender its fuel and water requirements, and consuming coal at the average rate of six pounds per horse-power hour. In another picture, differing in form but not in kind, we have the central stations of the country, with an aggregate condensing steam-generating capacity of, say, 20,000,000 horse-power, and consuming coal at the rate of about 1½ pounds per electrical horse-power hour. Instead of 65,000 portable power-plants, averaging about 1000 horse-power each, as is the case of the steam locomotive, there are approximately 5000 stationary, steam-generating, central-station plants averaging, say, 4000 horse-power each. No one would think of trying to supply these central-station power-houses with wheels and track, together with water and fuel supply, and have them move about the country drawing huge trains.

As a measure of conserving our coal supply, it might easily be suggested that with increased capacity and interconnection these stationary power-plants should do all the steam generating; also that these central stations in turn should transmit their electrical output to the numerous locomotives, they being converted from steam to electric drive. This arrangement would also utilize thereby a tremendous diversity factor. This diversity factor would be the equivalent of the 65,000 steam locomotives. The Bonbright essay contest brought out the forecast that in 1930 the steam-generating capacity of central stations would be about 30,000,000 horse-power, but doubtless this would require a still further increase should there be a material demand caused by steam-railway electrification. The overall thermal efficiency of such a system with modern power-plant equipment would be about 12 per cent., as compared with about six per cent. for the steam locomotive. These percentages compare the total

B.t.u. heat value in the fuel burned under the boilers with the mechanical equivalent available at the rims of the locomotive drivers. Thus the query again arises as to why we have 65,000,000 horse-power in portable steam power-houses rolling around the country, instead of electric locomotives. There must be some merit in the retention of the reciprocating, non-condensing steam-engines, even though their type has long since been discarded in stationary prime movers. Obviously, the answer can not be found in the thought that their maintenance cost is in many instances three times that of the electric locomotive, and in five years amounts to as much as the initial cost; that they require roundhouses and turn-tables; create a smoke nuisance; are not suitable for underground operation; incur losses in time and money-making stops for water and fuel; require more double tracking and terminal facilities; wear out brake-shoes instead of returning useful energy to the system on descending long grades; are available only 45 per cent. of the time, or less; consume at least twice as much fuel; expend 10 per cent. of their capacity in supplying their own fuel requirements; and experience difficulty in maintaining steam conditions in winter weather. Neither can the answer be found in the thought that there are not competent engineers to design, and large factories to manufacture, electric locomotives.

In stationary power-plants of any moment to-day, except those using steam for heat or processing, there is scarcely to be found a reciprocating, non-condensing steam-engine. These have been superseded, have suffered through obsolescence, and their manufacturers have been forced to discontinue, or have converted their factories to the manufacture of rotating, condensing engines—that is, steam-turbines for driving electric generators. After all this change in stationary prime movers, the query persists as to why the continuance of the reciprocating steam locomotive. With such an array of statements there is room for serious confusion which may fog the issue and do injustice to both steam and electric locomotives. Let us, therefore, state the answer as clearly as the involved conditions permit. Steam-railway electrification has not become more general in the United States:

1. Because of important matters pertaining to finance.
2. Because it has been thought that the steam locomotive has a field of its own where electrification might prove uneconomical.

MATTERS PERTAINING TO FINANCING

Steam-railroad systems differ materially from all other institutions to which electricity has been applied. The chief difference is that a single locomotive can not well be electrified without making a provision by overhead lines and substations throughout the entire system, or a division of it, to take care of the single electrified locomotive. Such a provision would not be feasible without converting all of the steam locomotives to electric drives, and here the matter of magnitude becomes a serious obstacle. Such a change immediately becomes revolutionary rather than evolutionary; incurs radical departures from long-established customs and landmarks; and involves large capital commitments; and all this in the past has required consideration without precedent or experience to follow. It is not surprising that, under such circumstances, capital has been timid in taking the initiative. How could capital be sure that the interest on the investment in electric locomotives, overhead material, and substation, plus the cost of electric energy, might not be greater than the cost of steam-locomotive operation.

Obviously, pioneers willing to make the trial based on engineers' calculations were needed. Within the last fifteen years some electrification has crept in—probably 720 locomotives, with a mileage of about one per cent. of the country's total. Each year is adding valuable knowledge, through actual experience, available for the steam-railroad executives and their engineers, so that when the roads have finally emerged from all the effects of war conditions, and have otherwise oriented themselves to new conditions, they can with more confidence and assurance address themselves to the pressing need for electrification where justified. This need for electrification of railroads, where warranted, is only in keeping with those demands which have led to electrification in practically all fields of human endeavor. The magnitude of the problem is well illustrated if we think of the electrification of all the 250,000 miles of our railroads at, say, $40,000 per mile, which would call for an expenditure of $10,000,000,000. This sum is $3,000,000,000 in excess of the estimated aggregate wealth of all our central stations to-day.

STEAM-LOCOMOTIVE OPERATION

No generalization is permissible with respect to whether or not a railroad should be electrified. Each case requires careful analysis

and study, especially where traffic is light and the profile level. However, there are certain characteristic conditions of operation which are determining factors, and which might be classified somewhat as follows:

1. Serious grades.
2. Congested tracks, terminals, and yards.
3. Unfavorable fuel and water conditions.
4. Favorable supply of electric energy.
5. Tunnel operation.
6. Legal bans on smoke and noise.
7. Weather conditions affecting steam supply.

When one or more of these conditions exists as a controlling factor, the possibility of electrification should be seriously considered. Otherwise, the steam locomotive, with its self-contained power-plant, seems to justify itself on economic grounds.

Electrification of steam railroads has been advocated to some extent on the grounds of fuel saving but, generally speaking, and as previously mentioned, this view is necessarily based only on the thought of conserving our national resources and not on the economy of railroad operation. The reason for this is that, whereas about half the fuel is saved by electrification, another expense is introduced which in a large measure offsets this fuel saving. This expense is represented by the interest charge on the cost of transmission lines, substations, overhead construction, and other electrical equipment. A cheap and plentiful supply of fuel has been cited in the past as a retarding factor of electrification, but this is erroneous, as witness the electrification of such railroads as the Norfolk and Western through the heart of the coal-mining district of West Virginia. It is true, however, that with electrification only half as much coal need be hauled, and this hauled once, namely, to the central station, returning the empty cars to the mine. With steam operation, twice as much coal is hauled, and this hauled twice—first to the coaling station and second on the locomotive tender, and twice as many empties returned to the mines.

We are informed that over a period of years the freight transportation requirements for a large city in ton-miles have increased 3½ times as fast as the population, and the urban population is estimated

to have increased 100 per cent. during the last 25 years, while the rural population has increased but 14 per cent. Thus, as traffic increases, the large problem facing the steam-railroad executives becomes that of providing rails and terminal facilities for handling the greatly increased volume of traffic. Further, it is estimated that about one-third of the total wealth in American railways is invested in the main terminals and facilities in the cities through which the roads operate. Thus we have an insight into the responsibilities of the railway executive, and in all modesty offer him increased capacity of existing tracks and terminals by electrification as a substitute for investment in more real estate and trackage.

During recent years, steam-locomotive operation has shown a marked increase in efficiency. The American Railway Association reports that for all the locomotives in service on American railroads the average fuel consumption—that is, the amount of coal used to move 1000 gross tons of freight and equipment—has decreased from 160 pounds in 1923 to 148 pounds in 1924, and to 138 pounds in 1925. Such improvements are praiseworthy, but there is danger of unduly stressing the fuel efficiency of the locomotive, which is only one of a number of principal expenses, and even this is offset by interest charges in the case of electrification. Such consideration of fuel economy obscures the fundamental problems which must be faced; namely, more traffic carried over existing tracks and greater capacity in terminal facilities. To both these problems electrification offers a solution.

One of the large steam-railroad electrifications, which has been in operation for about nine years, is that of the Chicago, Milwaukee & St. Paul. In view of the unjustified statements in some financial circles to the effect that the receivership of this road was brought about in part by excessive expenditures for electrification, a careful study of the report issued in February, 1925, by this railroad company on the economies secured by electrification, is earnestly recommended. Bearing in mind that bondholders are creditors, and stockholders are partners, it is apparent that the reason for the receivership of this road was the preponderance of outstanding bonds aggregating $470,000,000, as compared to the outstanding stock of $234,000,000. The report shows that the gross expenditure for electrification totaled less than $23,000,000, and the net investment, after deducting credit for equipment replaced and used elsewhere, totals $15,625,000. This

amount is 3.3 per cent. of the bonded debt, and obviously is insignificant. One of the outstanding facts of this report is that during the 8½ years following the installation of the first electrical equipment, more than $19,000,000 have been saved over what would have been spent for steam operation. After paying the interest and depreciation charges, a saving of $12,400,000 still exists. In comparing the kind of power, the report brings out the fact that a saving in crew expense, amounting to $672,000 per year, is accomplished.

The report further shows that the annual cost of up-keep for the electric locomotives is less than six per cent. of their initial cost compared with 25 per cent. of the initial cost of steam locomotives for the same period. Annual expenditures for maintenance of substations and overhead lines are about one per cent. of their total first cost. Regarding availability of the electric locomotive, the Chicago, Milwaukee & St. Paul figures show 85 per cent.

Subsequent to the above railway company report, Messrs. Coverdale and Colpitts, engineers employed to make an independent study of the physical conditions of the road, state in part as follows:

> "Electrification of parts of the St. Paul lines in the opinion of the engineers has justified itself instead of being one of the causes of the Company's failure, and the electrification of additional parts of the road is recommended."

The following information is extracted from the St. Paul report showing a comparison of cost of electric and steam operation as of the year August, 1918, to July, 1919, inclusive, covering the Rocky Mountain divisions—a distance of 438 miles of electrification from Harlowton, Mont., to Avery, Idaho.

	Steam	*Electric*
Gross ton-miles, passengers and freight	2,864,695,000	2,864,695,000
Expenses related to power		
Locomotives		
Carrying charges on investments	$ 178,383	$ 240,894
Maintenance cost, including maintenance of shops	1,268,824	440,833
Housing and hostling cost	281,396	102,736
Cost of lubrication and other supplies for locomotives	57,585	28,030
Fuel and electricity		
Cost of coal, oil, water, and electric current	1,606,507	851,908
Carrying charges on investment in facilities	48,195	484,189
Maintenance cost of facilities	33,730	86,532

	Steam	Electric
Cost of enginemen and motormen	733,070	411,508
Train and yard expenses		
Cost of trainmen and yardmen	639,144	412,453
Train and yard supplies and expenses, including brake-shoe, wheel, and draft-rigging wear	42,014	13,211
Signal and interlocker expenses		
Carrying charges on investment		(Net) 11,246
Cost of maintenance	52,131	47,671
Cost of operation	40,841	31,517
Work-train expense		
Equal amount of work both periods	74,721	62,415
Expense of superintendence	284,906	262,055
Total expenses and charges	$5,341,447	$3,486,798
Net savings by electrification	$1,854,649	

With respect to the electrification of steam railroads, and in the light of the difference of opinion of leading engineers as to the merits of the various systems, it is of the utmost importance, from the standpoint of national defense and the mobilization of our industrial resources, that those railroads which adopt electrification select the system, or systems, which will permit of universal interchange and maximum economy. The importance of this was stressed by Secretary Hoover and others in their addresses before the American Institute of Electrical Engineers on May 15, 1925, on the subject of a uniform railroad electrification system.*

INTERNAL-COMBUSTION PRIME MOVERS

The use of an internal-combustion engine direct connected to a generator, which, in turn, supplies current to motors geared to axles, makes possible a drive which in some respects is superior to the steam locomotive. Developments along this line are largely covered by two types—those which use gasoline as fuel, and those which use oil as fuel.

When gasoline is used, it is common practice to-day to build a power-plant on a passenger coach with operation not unlike that of an automobile, except that the power transmission from the engine to the wheels is electrical rather than mechanical. Cost of operating

*Journal A. I. E. E., v. 44, p. 663-672.

steam passenger trains serving very light traffic has made it necessary either to abandon the steam service or adopt a less expensive method of operation. A large amount of such traffic is being absorbed by automobile transportation, and this is an important contributing factor pointing to the necessity of providing remunerative railway service at low operating cost. The gas-electric passenger car is designed to meet this condition, and reports from those in operation reflect the satisfaction of operating executives who have had an opportunity to check the economies effected. Many railroads are operating in local main-line and branch-line service, a train consisting of a locomotive; a combined passenger, baggage, and smoking car; and a coach. Such a train is manned in some instances by a crew of five men, and the operating expense varies up to $1.50 per train-mile. A gas-electric driven car, with or without a trailer, will readily perform this service at an operating cost below 40 cents per car-mile.

The report of the Committee on Heavy Electric Traction, read before the American Electric Railway Engineering Association on October 5, 1925, contains the following:

ST. LOUIS-SAN FRANCISCO RAILWAY OPERATING EXPENSES, NINE GAS ELECTRIC CARS, JULY 1, 1922—JUNE 30, 1924 (CARS BUILT IN 1911)

	Gas electric	*Typical steam train*
Total motor car-miles	566,508	....
Total trailer car-miles	256,018	....
Total car-miles	822,526	....
Wages per train-mile	17.67c.	28.80c.
Fuel and lubricants	8.78c.	18.60c.
Running repairs	3.01c.	....
Classified repairs	4.68c.	31.40c.
Miscellaneous and supplies	0.67c.	4.50c.
Total expense per train-mile	34.81c.	83.30c.
Total expense per car-mile	24.00c.	....

The gas electric cars operating upon the St. Louis and San Francisco Railway have a weight of 104,000 lbs., 70-ft. body, 11-ft. baggage space, 8-cylinder gas engine, 8″ × 10″, running at 550 rpm, and two 110 HP motors. Approximately 100 of these cars have been built and put into operation on various lines, but manufacture was discontinued during the war due to expediency and also the high weight and price of the equipped car. While the lighter and less expensive cars now sold are expected to supersede the

heavier gas electric cars previously built, it is instructive, nevertheless, to note the reasonable cost of operating the older equipment after it had been in operation a sufficient term of years to reach what might be accepted as stable maintenance expense. . . .

The gas electric locomotive enjoys the advantage of a light, inexpensive, high-speed engine construction, but utilizes high-priced fuel. Apparently the gasoline engine application to locomotives is best adapted to the smaller capacities.

During the past year the first application in this country of the Diesel oil engine to locomotive drive has been put into demonstration service on several railroads. This engine is of the semi-Diesel type, runs at 600 revolutions and drives through electric generators and motors geared to the axles in the usual way. Owing to the low price of fuel available for engines of the Diesel type, its application to locomotive drive offers an attraction in fuel economy when compared with steam engine operation.

Early in November, an oil-electric car on the Canadian National Railway made the run from Montreal to Vancouver (2937 miles) in 67 hours. During the whole of the trip, the engine of the car did not stop. The average speed for the trip was slightly under 43.5 miles an hour. Fuel consumption averaged about five miles per gallon.

In present practice, the oil-electric locomotive supplies the demand for just such special conditions as are called for by the Kaufman Act of New York state applied to freight-shifting engines in New York City where noise and smoke are prohibited. In this case, the elimination of the overhead trolley is also demanded. To this end, the various railroads, which find it necessary to shift freight on lower Manhattan Island, have purchased 60- and 100-ton, oil-electric locomotives for this purpose.

The 100-ton, oil-electric locomotive purchased by the Long Island Railroad, on December 17 completed the 537-mile trip from Erie, Pa., to Greenville, N. J., with a 350-ton trailing load with its own fuel and water supply. The locomotive consumed 473 gallons of fuel, the cost being 4.36 cents a mile. The total cost of the run for both fuel and lubricating oil was $26.15.

Analyzing these interesting results from the viewpoint of thermal efficiency, fuel oil supplied to an internal-combustion engine develops an efficiency of 30 per cent., or more, at the engine shaft. After passing through the electric transmission, the energy available at the rim of the locomotive wheels is still 24 per cent. On this basis, the oil-electric locomotive will run four times as far as the oil-fired steam

locomotive, both using the same amount of fuel. The availability and maintenance of these oil-electric locomotives remains to be determined from actual operating experience, but these have been estimated as 80 per cent. for availability, and 10 per cent. of initial cost for maintenance.

TERMINAL ELECTRIFICATION

While there are a number of cities which could be used as illustrating the need of terminal electrification, much interest centers about New York City, the greatest terminal in the world. For this reason the conditions relating to New York are of the most interest. As well as being a great railroad terminal, it is also a great seaport, so that we have here a combination which makes for magnitude of congestion, especially when it is realized that this congestion centers largely on Manhattan—a strip of ground 12½ miles long and 2½ miles wide at the point of greatest width.

We are all measurably familiar with the passenger transportation of the railroads with terminals on Manhattan Island, all of which are electrified, namely, the Pennsylvania, the New York Central, and the New York, New Haven and Hartford. The reasons for electrification of these passenger terminals and the results obtained are now matters of record. There are about nine other railroads that discharge passengers and freight with New York as a destination. Seven of these railroads terminate along the New Jersey shore of the Hudson River, and handle their passengers either by ferry or electrified subway.

What has been said thus far in connection with these terminals has referred specifically to passenger transportation, but how about the handling of freight of which 4,000,000 tons annually are foodstuffs, and in part perishable, requiring expeditious handling? The total freight to, from, and through what is known as the Port of New York amounts annually to 75,000,000 tons, while in addition to this there is the corresponding sea-going tonnage of 45,000,000 tons handled by 8000 ships.

Those railroads referred to as having their rail terminals on or near the New Jersey shore of the Hudson River have freight stations on the opposite shore of the river. After their arrival at the New Jersey shore their freight cars are run on to car floats which are pro-

vided with tracks, each float having a capacity of about twelve cars. These car floats are then towed across the Hudson River, or up the East River and the Harlem River, to their various docks. The freight cars are then either moved by steam locomotives to the different railroad freight stations on the New York shore, and unloaded; or are unloaded directly into pier sheds from which the freight is trucked away. About 830,000 cars are thus handled annually.

The Manhattan Island freight stations on the waterfronts, sandwiched between steamship piers and ferry ships, have led to such street congestion through carting and trucking of incoming and outgoing freight, as to cause an intolerable condition. In like manner, congestion exists in New York harbor due to the handling of numerous car floats. These are slow-moving vessels, difficult to maneuver quickly, and consequently they cause delay to ferries and other more rapidly moving ships. To relieve this condition, a body has been organized known as the "Port of New York Authority." This organization is made up of the commissioners of the states of New York and New Jersey, in co-operation with the federal authorities, to study the entire traffic situation and make recommendations for relief. The Port of New York includes portions of the two adjacent states together with the waterways of the Hudson and East rivers; also New York Bay. It has a total shore-line of 800 miles, and a population of about 8,000,000. The Port of New York Authority has made its study and has recommended a comprehensive plan for the entire port, but approval by the interested parties of the plan as a whole has not yet been secured. Certain parts, however, have been approved and are being carried out.

Briefly stated, that part of the plan for the relief of Manhattan Island contemplates the abandoning of the present Manhattan freight stations of the railroads on the Hudson, East, and Harlem rivers, and in place of these there would be constructed in various parts of Manhattan Island at the centers of greatest distribution certain universal, underground, freight stations. These universal stations, or terminals, contemplate handling freight of all railroads and will have erected above them large warehouse buildings. Those railroads which approach from the New Jersey shore will be stopped some distance back from the Hudson River waterfront, where their freight will be transferred to wheeled containers and rolled into especially constructed

cars for transfer to Manhattan. These transfers will be made by what has come to be known as the "automatic electric railway system," which will deliver freight to nine universal freight terminals. These universal stations will be at a level below ground sufficiently deep to permit two levels of other forms of subways between it and the surface. The only standard freight-cars which will be delivered to the universal stations will be refrigerator cars carrying perishables. On this automatic electric railway, numerous electric trains made up of special motor-cars will follow each other under automatic control and without crews. One of the provisions for operation arranges for a trailing dead section of track behind each train to avoid collisions. The trains will move from station to station in Manhattan discharging and taking on freight at the various universal stations. Each car is capable, however, of manual operation by an attendant either walking along the platform or standing on the car.

This particular part of the plan has not yet been approved by the parties concerned, but, even if it should be approved in the near future, a considerable period of time would necessarily be expended in carrying out the work, and in the meantime traffic congestion continues. Pending the ultimate issue, it is now proposed to build universal freight stations on Manhattan and operate them with surface-trucking service from the present New Jersey terminals. The trucks would, in a sense, be a substitute for the car floats, and will travel through the new vehicular tunnel under the Hudson River as well as on the present ferries, and will carry the freight after it has been transferred to special containers. It has been shown that this will greatly relieve congestion both on land and water and release waterfronts on Manhattan for other purposes. The location and construction of the universal freight stations in Manhattan for this trucking service will be such as to be readily adaptable for the automatic electric-railway service at a future date.

We have all become so familiar with electrified passenger transportation underground, or through tunnels, that it has become commonplace, especially in New York. Our city planning work in congested centers has now led to most extensive handling of freight underground. Emphasis is laid on the fact that all this terminal railway activity is made possible only by electrification. The work of the Port of New York Authority is not unlike similar activities of the

Port of London Authority, as well as that of Liverpool. The handling of freight in this manner accomplishes savings in many ways, and these are such that from a financial standpoint it is feasible to sell interest-bearing securities to provide funds for such an undertaking, as well as to make provision for sinking-funds for the amortization of the debt.

In connection with this New York activity, it is interesting to bear in mind also that the topography of the so-called "Golden Triangle" of Pittsburgh is similar in some respects to the lower portion of Manhattan. One difference is that the shores on the far sides of the rivers in Pittsburgh, are, in many cases, precipitous bluffs; also, the Pittsburgh area involved is only about 218 acres, as compared with the corresponding New York City area of 4000 acres, the latter being the area south of Forty-second Street.

The annual rail and water tonnage in Greater Pittsburgh amounts to about 190,000,000 tons annually, and, while this is greatly in excess of New York tonnage (120,000,000) it is of a totally different nature, including such raw materials as iron ore, pig-iron, and steel billets; also coal and coke for industrial uses.

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the William Penn Hotel, Tuesday, April 20, at 4:40 P. M., President William E. Fohl presiding, Messrs. Ladd, Hunter, Weldin, Fieldner, Hopkins, Shaw, Covell, Rice and the Secretary being present.

The minutes of the last regular meeting, held March 16, were approved without reading.

Applications for membership from the following gentlemen, having been published to the Society pursuant to the action of the Board, were elected to membership:

MEMBERS

Bankson, Ellis E.
Ebersole, F. Leslie
Godard, Ray Stewart
Hazeltine, H. L.
Hefft, Joseph S.
Thorne, John Mueller

ASSOCIATE MEMBERS

Brown, William Edward
Fulkman, John A.
Mansfield, Myron G.
Townsend, J. F.
Manchester, George Earle

ASSOCIATES

Simons, Donald M.
Ramsey, William Guy

JUNIOR

Wilson, Charles Alexander McKinley

Applications for membership were received from the following gentlemen and their names ordered published to the Society. Assignment to the various grades is as follows:

MEMBERS

Dake, Walter M.
Dibble, Robert Horace
McCune, William H.
Strickler, Elmer V.

ASSOCIATE MEMBERS

Elwell G. Randolph
Latimer, George B.
Saurbrey, Alexis
Williams, Frank Way
Rigdon, C. Reade

ASSOCIATE

Orr, Ralph Vincent

JUNIORS

Dodworth, Jr., James Russell
Odell, John Dwight
Hale, William Thurber

The Secretary reported the death of S. V. Huber, who joined the Society in 1895 and died April 8, 1926.

The report of the Secretary showing the financial condition of the Society at the close of business March 31, having been audited by the Finance Committee, was approved.

In the absence of Mr. Clifford, Chairman of the Entertainment Committee, the Secretary reported that plans were completed for the proposed trip to Cleveland on April 30 and May 1. The Committee has no other definite plans at this time.

Mr. Weldin, Chairman of the House Committee, reported an evening attendance of 594 for the month of March.

In the absence of Mr. Affelder, Chairman of the Membership Committee, the Secretary stated that the Membership Committee had held one meeting during the month to go over applications received since the last meeting and transact any other business coming before the Committee.

The President stated that Max Hecht, Chairman of the Industrial Museum and Chairman of the Pittsburgh Section of the American Chemical Society, had approached him in regard to a joint meeting of these two organizations on Thursday evening, May 20, and that after discussing the matter with the Secretary it was found that we had a meeting for Tuesday evening, May 18. Mr. Fohl stated that he felt it would be unwise to hold two meetings in one week and therefore suggested that the May 20 meeting be used as our regular monthly meeting. This met with the approval of Mr. Hecht and his committee, and if the Board agreed we would call this our regular monthly meeting and eliminate the Tuesday evening meeting. It was moved and carried that the recommendation of the Committee be approved.

The Secretary presented a letter from the Pennsylvania State College asking that we appoint delegates for the election of trustees to be held in June. It was moved and carried that the President be authorized to appoint these delegates.

The question of the Bill for the Formation of a National Department of Public Works, brought up at the last meeting of the Board at the suggestion of Mr. Knowles, was brought up for discussion inasmuch as no action was taken at the last meeting, due to the small attendance.

After a general discussion, it was moved and carried that the Secretary be instructed to write Mr. Knowles thanking him for calling the matter to our attention and for his interest in attending the last meeting of the Board, and stating that the Board felt that, inasmuch as the Society had already gone on record as favoring the formation of a Department of Public Works, and further, that the proposed Bill had been given a great deal of study by the American Engineering Council, who sponsored it, the Board did not feel that they were qualified or competent to criticize it.

The Secretary presented a letter from Mr. Knowles suggesting that the Society take action in approving the passage of Bill HR-9397, providing for an Inventory of the Water Resources of the United States.

After a general discussion, it was moved and carried that this matter be referred to the Civil Section for their action.

The meeting adjourned at 5:45 P. M.

K. F. Treschow, *Secretary.*

JOINT MEETING OF THE PITTSBURGH SECTION, AMERICAN SOCIETY OF MECHANICAL ENGINEERS, AND THE MECHANICAL SECTION, ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

The regular bi-monthly meeting of the Mechanical Section of the Engineers' Society of Western Pennsylvania was held jointly with the Pittsburgh Section of the American Society of Mechanical Engineers, Wednesday, April 7, at 8:15 P. M., in the Blue Room of the William Penn Hotel, Chairman William Shaw presiding, 66 members and visitors being present.

The minutes of the last meeting, held February 2, were read and approved.

No further business coming before the Section, the paper of the evening, on "Automatic Control of Combustion," was presented by T. A. Peebles, Chief Engineer, The Hagan Corporation, Pittsburgh, Pa.

The ensuing discussion was participated in by: Arthur McGonagle,

Consulting Engineer, Pittsburgh; E. M. Boulton, Elec. Engr., Westinghouse Elec. & Mfg. Co.; Joseph Breslove, Consulting Engineer, Pittsburgh; G. G. Bell, Mgr. Power Development, West Penn Power Company; William Shaw, Asst. to Power Engr., National Tube Company; George B. Page, George B. Page Co., Pittsburgh; and the author.

On motion, duly seconded and carried, a vote of thanks was extended to Mr. Peebles for his very interesting paper.

The meeting adjourned at 9:45 P. M.

K. F. TRESCHOW, *Secretary.*

REGULAR MONTHLY MEETING

The 438th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Blue Room, William Penn Hotel, Tuesday, April 20, at 8:10 P. M., President William E. Fohl presiding, 60 members and visitors being present.

The minutes of the last regular meeting, held March 16, were approved without reading.

The Board of Direction reported the election of six applicants to the grade of Member; five to the grade of Associate Member; two to the grade of Associate and one to the grade of Junior, and the receipt of 13 applications for membership. There was one reinstatement and six resignations were accepted and one death reported.

No further business coming before the Society, Dr. Heber D. Curtis, Director, Allegheny Observatory, Pittsburgh, Pa., presented an address on "My Recent Trip to Sumatra."

On motion, duly seconded and carried, a vote of thanks was extended to Dr. Curtis for his very interesting talk.

The meeting adjourned at 9:50 P. M.

K. F. TRESCHOW, *Secretary.*

STEEL WORKS SECTION

The regular bi-monthly meeting of the Steel Works Section of the Engineers' Society of Western Pennsylvania was held in the Blue Room, William Penn Hotel, Tuesday, April 27, at 8:25 P. M., Chairman A. C. Fieldner presiding, 60 members and visitors being present.

The minutes of the last meeting, held February 23, were read and approved.

There being no further business coming before the Section, the paper of the evening, on "Gas Scrubbing in the Steel Industry," was presented by W. G. McGurty, Engineer, Bartlett-Hayward Co., Baltimore, Md.

The ensuing discussion was participated in by: Sidney R. Bellows, Engr., Blackstone Mutual Fire Ins. Co., Providence, R. I.; E. P. Jump, Test Engr., Carnegie Steel Co., Duquesne, Pa.; G. M. Kirkpatrick, Sales Engr., Andrews-Bradshaw Company; L. E. Riddle, Gen. Supt., City Blast Furnace, Carnegie Steel Co.; F. W. Sperr, Jr., Director Research, The Koppers Company; and the author.

On motion, a vote of thanks was extended to Mr. McGurdy for his very interesting and instructive paper.

The meeting adjourned at 9:17 P. M.

K. F. TRESCHOW, *Secretary.*

VOL. 42 JUNE 1926 No. 5

PROCEEDINGS
OF THE
ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA

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PROCEEDINGS OF THE

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INCORPORATED 1880

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No paper read before the Society shall be published elsewhere before its appearance in the PROCEEDINGS, and no paper previously published shall be published in the PROCEEDINGS without authority from the Publication Committee.

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Incorporated 1880

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American Institute of Electrical Engineers. Journal

American Machinist

American Roofer

American Society of Civil Engineers. Proceedings

American Society of Mechanical Engineers. Journal

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Arkitektur

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THE LIBERTY TUNNELS AND POWER-PLANT*

By C. K. Harvey†

INTRODUCTION

Since the Liberty tunnels were placed in operation almost two years ago, it has been hoped that A. D. Neeld, Consulting Engineer in charge of their design and construction for the Commissioners of Allegheny County, would present a descriptive paper before the Society. Unfortunately, Mr. Neeld has been unable to comply with a request to do so. In the meantime, the Department of Public Works of Allegheny County has received numerous inquiries, from all parts of the country, for information and data as to various features. The answering of these requests by individual letters was quite onerous, and the speaker was instructed to prepare a pamphlet embodying, as far as could be foreseen, the information likely to be requested. This pamphlet is the basis of the present paper, which is intended only to serve until such time as an exhaustive paper can be presented by someone much more familiar with the subject than the speaker, who is in the somewhat anomalous position of describing before a technical society an engineering work with which he has had no connection in design, construction or operation.

GENERAL

The topography of Pittsburgh is such that avenues of vehicular transportation present many problems which are not found in other cities. This is particularly true of the region lying south of the Monongahela River and known as the South Hills district. The territory immediately adjacent to the river rises abruptly in an escarpment, known locally as Mt. Washington, which presents a barrier to easy communication with the land farther to the south and west. The Mt. Washington district, immediately south of the river, has for many years been reached by means of inclined planes for passengers and freight, but communication with the property beyond was possible only by means of circuitous routes over heavy grades.

*Presented March 16, 1926. Received for publication May 28, 1926.
†Assistant Engineer, Bureau of Bridges, Department of Public Works, Allegheny County, Pittsburgh.

In 1904 an electric-railway tunnel was completed from the vicinity of the south end of Smithfield Street through Mt. Washington. This tunnel is about 3600 feet long on an ascending grade of almost six per cent. and furnishes the means for direct street-car communication with all of the South Hills territory. The completion of this tunnel caused an increased interest in the development of this territory, which is very desirable as a residential district, both by reason of its high elevation (ranging in general from 400 feet to 500 feet above the elevation of down-town Pittsburgh) and because its situation is such that prevailing winds do not carry smoke and dirt to it from the industrial district.

For many years the question had been discussed of providing easier communication for vehicles to this desirable district. Many plans were proposed and studied with more or less elaboration for a period of possibly twenty years. Among them were the projects mentioned below. Fig. 1 indicates the location of the various projects.

EARLY PROJECTS

Haberman Tunnel. This was a high-level project proposed about 1907 or 1909 by Hermann Laub and F. I. Gosser. It contemplated a short tunnel 1900 feet long extending to high ground at Warrington and Haberman avenues in combination with a double-deck bridge across the Monongahela River. The upper deck of this bridge was to rise on a grade of 3.78 per cent. from Shingiss Street, on the Pittsburgh side, to the north portal of the tunnel, while the lower deck was to connect with Carson Street. The north portal of the tunnel would have been about 80 feet above that of the Liberty tunnels as finally built, while its south portal would have been 184 feet higher than the West Liberty Avenue portal of the Liberty tunnels. This project was discarded because of its heavy grade and the height of the bridge and the long climb from West Liberty Avenue to its south portal.

Haberman Tunnel Extension. This project, credited to W. M. Donley, was an elaboration of the preceding, involving a total tunnel length of 4600 feet, in two sections, separated by 1100 feet of open cut. This scheme was intended to combine the advantages of access

to Warrington Avenue with those of direct connection with the Saw-mill Run valley.

Bigelow Project. The late E. M. Bigelow proposed a tunnel from South First Street and Carson Street either to a portal in the vicinity of the Bell House (6280 feet long with a rising grade of 2.12 per cent.) or to a portal on Warrington Avenue southwardly from the south portal of the electric-railway tunnel (4800 feet long on a grade of 3.4 per cent.).

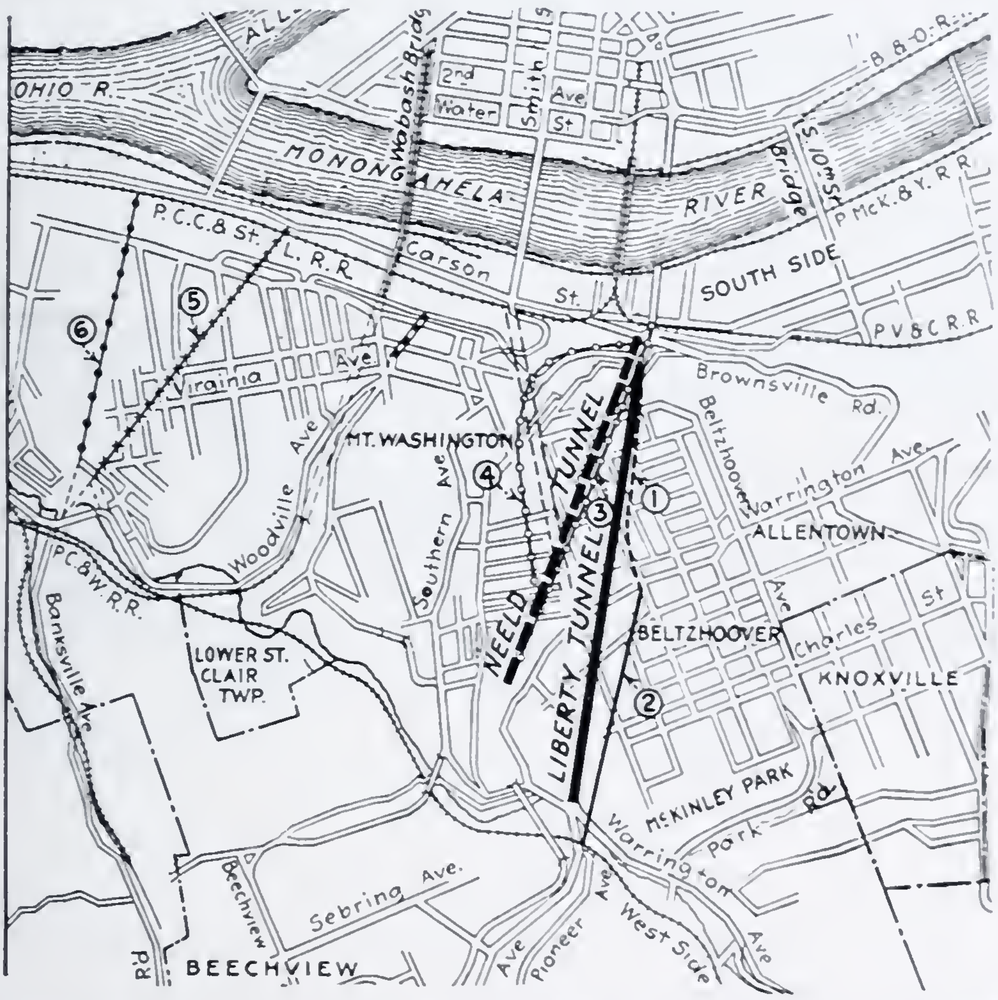

Fig. 1. South Hills Tunnel Projects. 1. Haberman Tunnel; 2. Haberman Tunnel Extension; 3. Morse Location; 4. "Open-Cut" Location; 5. Bigelow-Shalersville Tunnel; 6. Alternate Shalersville Project.

Neeld Tunnel. Of the earlier projects the most important is the Neeld tunnel, on which construction was actually begun about 1915. The north portal was located not far from that of the Liberty tunnels, but at a lower level, as it was intended to reach Carson Street at grade, and extended 4900 feet on an ascending grade of 2.88 per cent. to a point 67 feet below the grade of Warrington Avenue near the Pittsburgh Railways Company's car barns. Work was stopped on

this project for legal reasons, and at the time of the restudy of this location in connection with the final location of the Liberty tunnels the Planning Commission disapproved of the location of the north portal because of its connecting with Carson Street at grade and thereby interfering with traffic parallel to the river, and of the location of the south portal because of the heavy grade (six per cent.) of the approach along Warrington Avenue from West Liberty Avenue.

Similar objections were held to condemn the Bigelow project mentioned above. The several projects developed by E. K. Morse, using the south portal location of the Neeld tunnel, were considered objectionable for similar reasons.

Morse "Open-Cut" Location. Another study by Mr. Morse contemplated a tunnel, viaduct, and open cut in combination, beginning at Brownsville Avenue, near South Third Street. It proposed to ascend on a five per cent. grade along the face of the bluff; thence to proceed southwardly by 950 feet of open cut, 500 feet of tunnel, 1450 feet of open cut (maximum depth 200 feet) and finally, by surface and roadway—including a viaduct 1200 feet long, crossing over Sawmill Run—to West Liberty Avenue. This project was disapproved because of "its heavy grades, indirect routes and viaducts and the proposed depth of the open cuts."

LIBERTY TUNNELS

The culmination of all these preliminary schemes was in the tunnels as finally planned and now built and named the Liberty tunnels. Construction work was started in December, 1919, and the work was virtually completed and in operation, except the ventilating system, in May, 1924. The work was formally taken over by Allegheny County from the consulting engineer and contractor on September 1, 1924. A. D. Neeld, Consulting Engineer, of Pittsburgh, was in charge of the design and construction of the tunnels. Arthur McGonagle was consulting electrical engineer on the ventilating system. Stanley L. Roush, Architect, designed the fan-house building and supervised all architectural features. The contractor was Booth & Flinn, Ltd., of Pittsburgh.

The estimated cost based on the original contract for the tunnels

was approximately $4,800,000, and a bond issue of that amount was authorized. After the need of ventilation was demonstrated additional funds were provided, bringing the total amount available up to $6,050,000. The actual final cost was $5,994,642.83.

Dimensions. The Liberty tunnels as finally constructed consist of two tubes 59 feet apart on centers and 5889 feet long from portal to portal, this length including a 66-foot air-chamber at the exit end of each tunnel, the purpose of which is described later in connection with the ventilating system. The grade is 0.329 per cent. descending toward down-town Pittsburgh. The springing-line is six feet, six inches above the top of curb and the diameter at the springing-line is

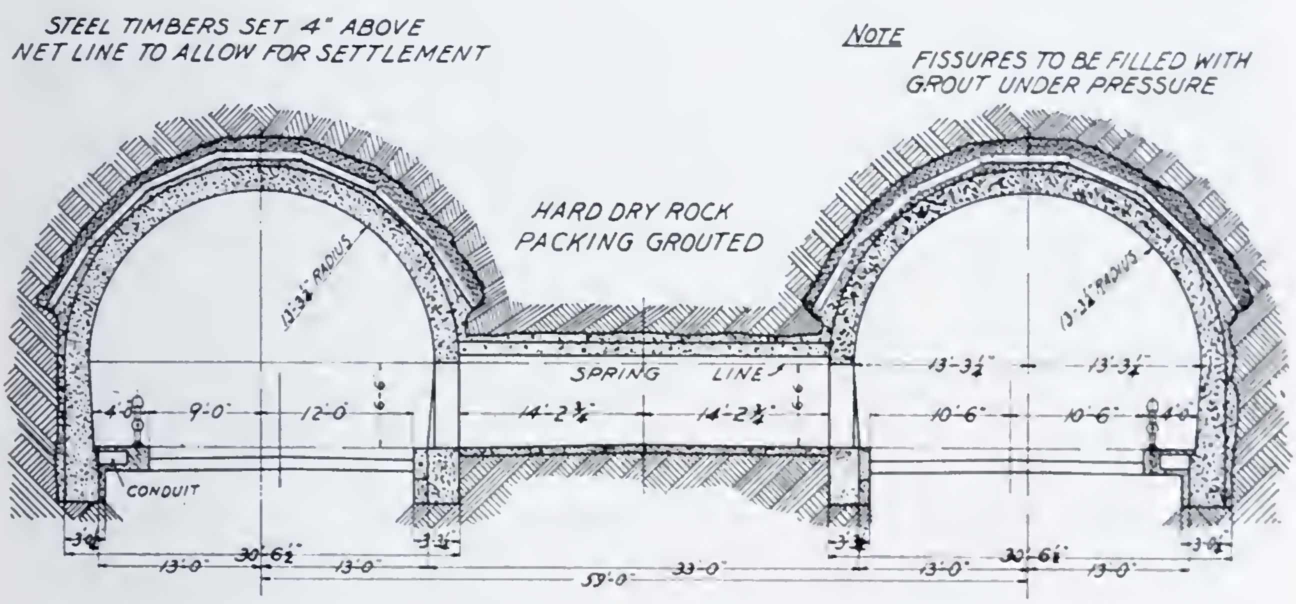

Fig. 2. Cross-Section of Tunnels.

26 feet, 6½ inches. The roadways are 21 feet between curbs, with a four-foot sidewalk to the right of the roadway in each tunnel. This sidewalk is separated from the roadway by a pipe hand-railing set 12 inches from the face of the curb. The wheel curb on the left-hand side is 12 inches wide. The curbs are 10 inches above the center of the roadway. The roadway is of one-course concrete, nine inches thick at the edges and 11 inches at the center, with a two-inch crown. Fig. 2 shows a cross-section of the tunnels, and Fig. 3 illustrates the north entrance.

Each tunnel has its own ventilating shaft, divided into four compartments. The shaft of the south-bound tunnel is 39 feet, 6 inches north of the middle point of the tunnel, and that of the north-bound

shaft is 89 feet, 6 inches north of the middle point of the tunnel; the shafts, therefore, being not opposite each other, but 50 feet apart, measured in the direction of the axes of the tunnels.

The ventilating shafts are vertical and uniform in cross-section throughout, except for round edges at top and bottom. The two exhaust compartments in each shaft are 10 feet, 10 inches by 13 feet each. The two supply compartments are 5 feet, 11¼ inches by 13 feet each. The four stacks are each 10 feet square and 110 feet high.

The difference in elevation between the intrados of the tunnel and the floor of the fan house is 199.23 feet, the fan-house floor being

Fig. 3. North (Pittsburgh) Portal.

level with the top of the shafts. Each intake and exhaust shaft is supplied by two fans, each fan being run by two motors. This enables the ventilation to proceed by using a part of the equipment at a time, gives extra capacity for emergencies, and allows repairs to be made without cutting off the air supply.

Ventilation. At the time of their completion, the Liberty tunnels were the longest vehicular tunnels ever built. Little was known as to the possible effects of poisonous gases discharged by motor vehicles in tunnels, and the design of the ventilating system therefore

called for considerable technical research and engineering investigation. It was necessary to forecast the number of vehicles in each tube; to determine the average amount of gas exhausted by each; to determine the dilution necessary to make these gases unobjectionable and harmless, and make other similar studies in order properly to design the capacity and size of fans required to ventilate the tubes. The United States Bureau of Mines contributed valuable services in these investigations.

As a result of these studies, it was decided to locate the venti-

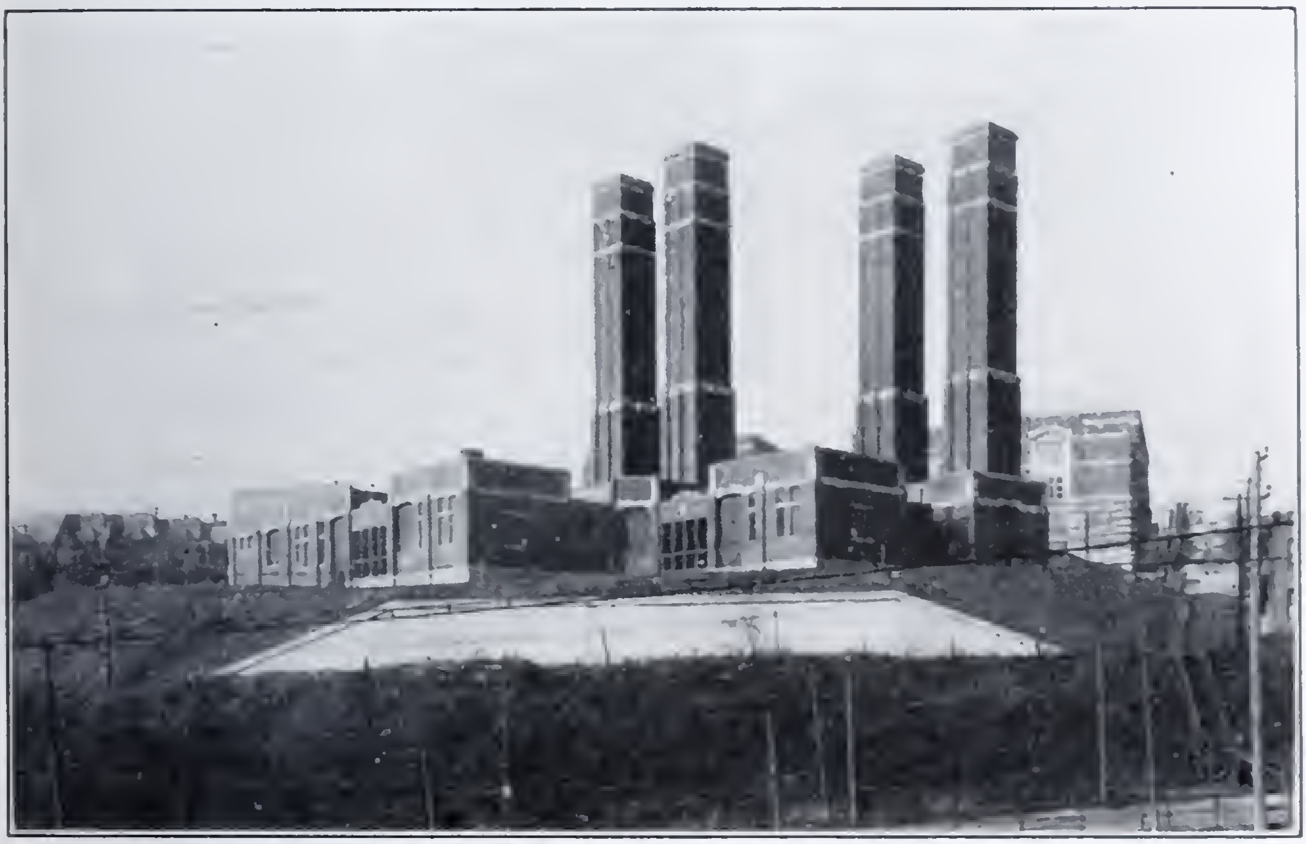

Fig. 4. Power-Plant (South Hills High School in Background).

lating plant on the hilltop near the center rather than at either end of the tunnels. This central location permits the removal of vitiated air after it has traversed half the length of the tubes, reducing by one-half the period of contamination. This central location of the power-plant likewise reduces the frictional resistance to the air which is forced through the tubes, thereby reducing the amount of power required. A view of the power-plant is shown in Fig. 4.

The movement of air in the tunnels, however, is not from both ends toward the center, as this would cause the current of air in the half length of a tunnel to be against the traffic. It was considered advisable to have the air move always in the same direction as the

traffic, so that the current resulting from the moving vehicles could be utilized. This was accomplished by drawing the air through one-half the length of each tunnel towards the center and blowing a supply of fresh air through the other half, away from the center; that is, one set of fans acts as suction fans and the other set acts as blower fans.

The air movement in each tube is as follows: In the tunnel carrying traffic away from down-town Pittsburgh, fresh air enters the tunnel with the traffic at the Pittsburgh (north) portal, moves with the traffic to the center, and is there drawn out through the exhaust compartments of the vertical shaft at the same time that the fresh air is being blown through the fresh-air supply compartment of this same shaft. This fresh air moves with the traffic through the remaining half of the tunnel and is exhausted at the South Hills (south) portal. In the tunnel carrying traffic towards down-town Pittsburgh, fresh air enters the tunnel with the traffic at the south portal, moves with the traffic to the center, and is there drawn out through the exhaust compartments of the vertical shaft at the same time that fresh air is being blown down through the fresh-air-supply compartments of this same shaft. This fresh air moves with the traffic through the remaining half of the tunnel and is exhausted at the north portal. Incoming fresh air from the fans is discharged near the middle of each tunnel through suitably designed nozzles which are turned forward in the direction of traffic. This arrangement prevents short-circuiting and consequent merging of the fresh air with the vitiated air which is being drawn out through the other compartments of the same shaft. The nozzles are about fifty feet beyond the opening of the exhaust shaft, and the only current of air in this space is that induced by the traffic and the incoming fresh air.

At each end of the tunnel a special construction has been used to provide a wind-break to prevent obstruction of the outgoing ventilating currents by winds. It consists of a wind trap formed by extending the tunnel some 75 feet beyond the face of the hillside and building two large openings in the roof of this extension, with side walls carried up high enough to form, in effect, low upcasts or stacks. The outgoing ventilating current can pass upward to the open air and at the same time an opposing current of wind from the outside entering the tunnel portal can pass up the first stack, when it is deflected by meeting the ventilating current. In practice this works very well.

Air-Pollution Studies. Extensive experiments were made in connection with the United States Bureau of Mines to determine the allowable amount of air pollution which would be innocuous to those passing through the tunnel. The table below shows the results of an elaborate series of experiments made by the Bureau of Mines to determine the amount of carbon monoxid gas produced by motor vehicles of different types under various operating conditions. It indicates the amount of carbon monoxid produced by various classes of automobiles and trucks loaded to one-half capacity and running on level grade.

TABLE I. CUBIC FEET OF CARBON MONOXID PER HOUR AT 65 DEGREES F. AND 29.92 INCHES OF MERCURY

Class of car	Racing	Idling	Miles per hour 3	6	10	15	20
Five-passenger	65	35	36	....	46	61	73
Seven-passenger	105	33	53	....	76	112	137
Trucks, up to 1½ tons	68	31	47	....	60	77	94
Trucks, 1½ to 3 tons	56	13	....	68	104	104	....
Trucks, 3½ to 4 tons	158	66	....	92	147	131	....
Trucks, five tons	105	50	....	110	152	....	....

Professor Henderson made an exhaustive investigation at New Haven to determine the effect on the human body of breathing air containing various proportions of carbon monoxid gas. Based on these tests on a large number of persons, it was determined that no harmful effects resulted from breathing, for a period of one hour, air containing six parts in 10,000 of carbon monoxid gas. Other tests resulted in the assumption that on a level road the average motor-car discharges 1.5 cubic feet of carbon monoxid per minute.

On this basis it was determined that each vehicle in the tunnel requires a fresh-air supply of 2500 cubic feet per minute. The assumed number of cars in each tube under full normal traffic conditions was taken as 114; hence the total fresh-air supply required is 280,000 cubic feet per minute for each tunnel, and this amount was made the minimum to be supplied to each tunnel. As each tunnel is served by two exhaust fans and two blowing fans, this duty was divided equally among the four fans, and the minimum duty of each fan was fixed at 70,000 cubic feet per minute.

In order to take care of increased traffic due to rush-hour periods, or any unusual condition, the fans were designed to give an increase in output due to increase in speed which would bring their delivery up to 140,000 cubic feet per minute each, or a total for each tube of 560,000 cubic feet per minute. Suitable provision is made for varying the motor speed, which allows the fans to discharge any desired quantity between the two limits as the traffic may require.

As a further precaution, and in order to take care of traffic jams or a fire in the tunnel, the speed of the fans can be increased 25 per cent. beyond the above mentioned maximum, which brings their capacity to 175,000 cubic feet per minute each, or a total for each tunnel of 700,000 cubic feet per minute, which amount, on account of the ejector effect of the air nozzles in the side walls of the tunnels, causes an air movement of over 1,000,000 cubic feet per minute through each tunnel.

Carbon Monoxid Control. During the early phases of the tunnel operation, a carbon monoxid recorder was installed experimentally by the United States Bureau of Mines. This ingenious device took a continuous sample of the vitiated air from the exhaust shaft of one of the tubes, and, by separating the carbon monoxid and burning it, gave a continuous record of the number of parts per 10,000. Six parts in 10,000 was set as the maximum permissible, and two parts was the maximum actually attained. By means of this the operators were able to tell when the maximum pollution could be expected, and could speed up their fans accordingly. The peak-loads were so regular that after a while it was found that the recorder could be dispensed with. The Bureau of Mines removed it, but if a machine of this kind were desired in future tunnel projects, the Bureau could no doubt supply the want.

Power Supply. Current for operation of fans, lighting, and other purposes, is obtained from several sources. One 11,000-volt line from Brunot Island station, and a second from the Colfax station of the Duquesne Light Company, supply current for power and for lighting. These are coupled together in the transformer room, and either or both can be used. A third 2200-volt line from the Warrington Avenue substation is an emergency supply for lighting the

tunnels, and another 110-220-volt, single-phase, emergency circuit is available for station lighting.

There are eight fans, and each fan is connected by a magnetic clutch with two direct-current motors. All the fan motors and magnetic clutches are controlled from a switchboard in the converter room.

Fan Operation. For a number of months, before the completion of the ventilating system, the tunnel was operated, with limited traffic, under natural ventilation. Since the ventilating system has been in operation, no attempt has been made to limit the spacing of vehicles or to control their method of operation, except such control of speeding and reckless driving as the traffic policemen may exercise. The maintenance men or traffic policemen can communicate with the operating room by telephone at any one of the cross passages between the two tubes, such passages being spaced about 500 feet apart along the tunnel. The present practice of operating the plant is to keep one supply and one exhaust fan in operation throughout the 24 hours for each tube, and to use all fans only during the day, the speed of all fans being regulated according to traffic conditions, the speed being increased just before rush hours so as to maintain ample ventilation during the traffic peak. Overload operation by switching in the second motor of each fan is resorted to only at times of congestion or similar emergency. There is no unnecessary duplication of equipment. Only such duplication is provided as is necessary to secure the continuous operation so vitally necessary to the safety of the public, and to provide for operating the plant at maximum efficiency.

Maintenance Organization. The operation of the tunnels is under the jurisdiction of the Department of Public Works of Allegheny County. The force required to operate the tunnels and power-plant consists of 20 men. The positions are, one superintendent, one clerk, three plant operators, four assistant plant operators, two electricians, five utility men, two traffic police, and two watchmen. Since the plant operates 24 hours a day, provision is made in the operating force for sickness and days of leave.

Real-Estate Values. The completion of the Liberty tunnels has had a very marked effect on realty values in the South Hills district.

There has been a large appreciation in value and volume of sales of improved property. Many high-class realty developments have been made and an enormous volume of building, principally of a residential character, has ensued. Although the construction and completion of the tunnels came at a time when real-estate values all over the country were increasing, there is no question but that a large portion of the increase in value and development in the South Hills district was directly due to this great improvement. This has been very marked in the Beechview and Brookline districts, in the city of Pittsburgh, and outside the city in the borough of Dormont and in Mt. Lebanon Township. This suburban territory outran all other sections of the city in the number of building projects in 1925. This condition continues, and the fact that residential building has slackened in other parts of the city, while it continues unabated in the South Hills district, shows the influence of the tunnels. It is confidently expected that this situation will not change, as the building of the Liberty bridge, a complementary part of the tunnel project, will make access to the South Hills very easy from the down-town district.

The "Traffic Jam." On Saturday morning, May 10, 1924, due to a street-car strike and the consequent unprecedented use of motor vehicles, a congestion of traffic occurred in the city-bound tube of the Liberty tunnels. The seriousness of the affair was considerably magnified in the newspapers. The following report, made by Charles M. Reppert, Assistant Director of Public Works of Allegheny County, and dated May 20, 1924, describes what occurred:

"The Liberty Twin Tunnels, because of the very urgent need, were thrown into operation a few months ago in advance of the completion of the mechanical ventilating system, which is a feature of the tunnels' design. This step was taken only after careful studies and experiments were made by the ventilating experts of the U. S. Bureau of Mines and after arrangements had been made with them to continually watch the air conditions in the tunnel. Traffic restrictions were likewise enforced. Since the tunnel has been in operation, the air conditions during the morning and evening traffic peaks have been such as to cause no alarm, I personally feel that this premature use of the tunnel, because of the great traffic relief it has provided for the people of Pittsburgh was fully warranted.

"Briefly what happened is as follows: A strike of street car employees went into effect Friday at midnight. (Fortunately this continued only for a few days.) The absence of car service caused automobile congestion in

down-town Pittsburgh, which was communicated for some distance along many of the inbound arteries of traffic notably along the Liberty Tunnel route from the populous South Hills. The traffic congestion, in respect to the Liberty Tunnels, extended from the Boulevard of the Allies, across the Smithfield Street Bridge over the Monongahela River, up Carson Street and Brownsville Avenue and through the inbound tunnel.

"According to the checker employed to count the vehicles using the Liberty Tunnels, 649 cars entered the in-bound tube between 7:30 and 8:00 o'clock in the morning, breaking all previous records. The traffic jam, originating in the business district, caused many automobiles to halt throughout the complete length of the tunnel. The ventilating effect caused by the machines in motion was thus interrupted. The orders given by the traffic officers to shut off engines while stopped, were ignored by many of the drivers of the machines. The large number of motionless machines in the tunnel discharging exhaust gases vitiated the air and caused some of the people to become affected. Many people became panicky, abandoned their machines and rushed for the exits. No doubt exhaustion and nervous hysteria had its effect as well as the air conditions.

"From an investigation which I ordered, I learn that 12 people were taken to the hospitals. All hospitals were visited by noon by Dr. W. J. McConnell, of the U. S. Bureau of Mines, and he found no cases of a serious nature and that a majority of the patients had been dismissed. There were no fatalities. Those affected to any extent were County or City employees engaged in clearing the tunnel and hence exposed for a considerable length of time.

"A sample of the tunnel air was taken about the time the people began abandoning the machines and analyzed by the U. S. Bureau of Mines' Chemists. The sample was taken among the machines and represents the worst air to which the people were exposed, but does not necessarily represent conditions throughout the tunnel. The sample showed 0.25 per cent. carbon monoxide and it is said that this concentration if breathed continuously would render a man unconscious in 30 to 45 minutes.

"The inbound tunnel was out of commission about six hours, as it required some time to haul out the abandoned machines and to restore properly controlled traffic regulations.

"It is to be regretted that the incident occurred. No new technical information may be gleaned from the experience. The danger of exhausting automobile gases within any confined enclosure, be it a garage or a tunnel, is already well known. It caused no reason whatever for modifying the proposed ventilating plans of the tunnels. It caused no change in the program of using the tunnels in advance of the completion of the ventilating system. The experience did, however, emphasize the necessity of having strict traffic control which will be continued—even after the ventilation system is completed."

Cost. The following tabulations show the actual cost of the Liberty tunnels under the original contract, the cost of extra work (due mainly to the necessity for providing ventilation and partly to temporary roadway at the north approach pending the building of the Liberty bridge) and the cost of fan house, stacks, and ventilating equipment.

The approximate quantities of the various materials encountered in the excavation were as follows:

Low-grade sandstone	40 per cent.
Shale	30 per cent.
Clay	30 per cent.

ORIGINAL CONTRACT

Item	Quantity		Unit price	Cost
Tunnel complete, exclusive of portals and approaches	5,714	lineal feet	$722.00	$4,125,508.00
Excavation, north approach	48,445	cubic yards	1.80	87,201.00
Excavation, south approach	23,703	cubic yards	3.00	71,109.00
Concrete masonry, north portal	9,918.8	cubic yards	10.00	99,188.00
Concrete masonry, south portal	5,480.6	cubic yards	14.00	76,728.40
Reinforcing steel bars	628,057	pounds	0.02	12,561.14
Reinforcing steel fabric	7,563	pounds	0.01	75.63
Pipe railing (2½-inch) (approaches)	348	lineal feet	2.00	696.00
Concrete curb (approaches)	2,233.6	lineal feet	1.35	3,015.36
Concrete sidewalk (approaches)	5,378	square feet	0.25	1,344.50
Sewers and water lines (approaches)				7,323.50
Sawmill Run bridge (approach)				57,923.30
Actual cost of original contract				$4,542,673.83

EXTRA WORK

Protection of slopes		$ 4,222.58
Extending side walls, etc.		9,862.00
Change and omission of terra-cotta ducts (credit)	$ 5,485.44	
Passageway between tunnels		28,490.00
Omission of 15-inch terra-cotta sewers in tunnels (credit)	12,900.50	
Enlarging tunnel section		119,024.74
Construction of ventilating shafts		181,239.15
Omission of street-railway tracks in tunnels (credit)	71,425.00	
Change in contract items 1-13		67,949.54

EXTRA WORK—CONTINUED

Item	Unit Price	Cost
Change in contract items 1-12		28,464.87
Reconstructing concrete sewer		15,385.48
Grouting		488.06
Excavating temporary roadway at north end of tunnels		37,420.50
Construction of roadway at north end of tunnels		12,969.30
Construction of curbs, walls, etc., at north approach of tunnels		7,309.86
Miscellaneous work to complete tunnels		13,150.65
Omission of bell mouth at north end of west tunnel (credit)	4,768.00	
Total credits	$ 94,578.94	
Total orders for extra work		$ 525,976.73
Fan houses and stacks	$228,577.30	
Extra work	4,607.06	
		233,184.36
Installing electric power and lighting equipment	$168,000.00	
Extra work	5,345.08	
		173,345.08
Ventilating fans and connections		57,736.00
Heating and plumbing	$ 6,900.00	
Extra work	296.00	
		7,196.00
Engineering		264,108.07
Property purchased		105,940.00
Property damages		179,061.70
Total construction cost		$6,089,221.77
Total credits		94,578.94
Total final cost		$5,994,642.83

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DISCUSSION

W. E. Fohl:* Mr. Harvey, with becoming modesty, has said that he is reporting on a project with which he was not immediately concerned. We all realize, however, that to report properly such a project requires engineering talent of no mean order. I think you will all agree that Mr. Harvey has performed this service very successfully. The paper is now open for general discussion.

V. R. Covell:† Mr. McGonagle, who is so familiar with the electrical equipment, might enlarge a little on some of those features.

Arthur McGonagle:‡ I did not come in contact with this proposition until after Mr. Neeld had decided on the system of ventilation and had decided on the air volumes to be handled. He had gone into the matter very thoroughly. He had even constructed a scale model of the tunnels and the ventilating ducts and had experimented in order to ascertain what effect the air currents would have

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†Chief Engineer, Bureau of Bridges, Department of Public Works, Allegheny County, Pittsburgh.
‡Consulting Engineer, Pittsburgh.

in the tunnels. He established some interesting data. You have heard Mr. Harvey's description that the fresh-air supply of the second half of each tube is brought down through ducts and delivered through nozzles in the side walls of the tunnel. These nozzles are set at an angle with the axis of the tunnel of about 2½ in 12 and Mr. Neeld determined that the ejector effect would amount to about 27 per cent. of the air delivered through the nozzles. In other words, there would be 27 per cent. more air moved through the tunnels than came out of the nozzles. This question is often asked by people handling air under those conditions.

When this problem was undertaken, no one knew how much ventilation was going to be required. We knew from the experiments of the United States Bureau of Mines what amount of CO would be given off by an automobile and how much air it would take to dilute it. But we could not tell how many automobiles would be in the tunnel. We knew that traffic would be heavier at some times than at others—heavier in the north-bound tunnels in the morning and heavier in the south-bound tunnels at night. That brought up the question of the kind of current to be supplied to the fan motors. It seemed very important that the arrangement should be flexible enough so that the motor speeds could be regulated to meet with maximum efficiency the varying demands of the tunnel ventilation. For this reason it was decided to use direct-current motors. This necessitated a converting plant to convert the alternating-current supply of the light company and thus give us as flexible control of the motors as we desired.

The question of lighting came up. That was gone into quite extensively. We had some very long lines. We had four lighting circuits in the tunnels, two in each tube, but they were not confined to the one tube. One circuit comes down the shaft and goes to the south end of one tunnel, crosses to the other tunnel and returns to the shaft of the other tunnel and up the shaft to the power-house. The second circuit parallels the first in the opposite direction. The same arrangement is applied at the north end. The lamps are connected to the circuits alternately, so if we lose one circuit we lose only half the light at one end of the tunnels. The system of lighting is a series incandescent system, enabling us to distribute over the long distances we had to carry the wires without using extra large conductors and

without having large drops in voltage, and variations in the light intensity.

The system of motor control which was adopted was to use shunt-wound motors with field control. The minimum speed of the motors driving the supply fans was 212. That corresponds to the air delivery that Mr. Harvey mentioned of 70,000 cubic feet to the minute. That is the speed at normal full load with all resistance out. By varying the field we increase that speed to about 425 revolutions, which corresponds to the 140,000 cubic feet per minute for each fan. That is the normal maximum. In order to go beyond that to 175,000 cubic feet of air per minute it means an increase of 25 per cent. of the supply, which is, of course, practically double the horse-power. Instead of putting in a motor of double the size we put in two motors and provided for connecting two motors to one fan. That brought up an interesting point. Those motors had to be designed and built and balanced so they would divide the load at equal speed. This was done very successfully. The control of these motors was so arranged that any fan could be started and operated up to 140,000 cubic feet per minute with either motor; but the second motor could not be cut in until both motors are up to that speed, and neither motor could be brought up beyond that speed until both motors are in.

We encountered another interesting point in the matter of fans, especially in the exhaust fans. When two fans of the type used on this work draw air out of a common chamber and deliver into a common chamber they will not divide the work equally, even when they are of the same size and are running at the same speed. One fan or the other will, as it is commonly expressed, "hog" the load. It is impossible to know which of the two fans, so arranged, will be affected. At one time this will occur to one of the fans, at another time to the other fan. Thus two fans operating in parallel might result in a fan motor being overloaded from time to time. We had two fans drawing the air out of the same tunnel chamber and delivering it to the atmosphere. If the two or more discharge connections were connected to a common stack, we would have a condition similar to that described. This was the reason for four stacks. The question of the supply fans was not subject to the same difficulties because the nozzle through which the air was delivered to the tunnels had contracted openings between the delivery main and the tunnel.

I should be glad if Mr. Neeld could be here to explain the various steps he went through in order to arrive at his conclusions. It was very interesting and a matter to which he gave very thorough study.

P. J. Freeman:* I happened to be associated very closely with Mr. Neeld in connection with the testing of the concrete used in the tunnels, as the Pittsburgh Testing Laboratory had been employed to make the crushing tests of the concrete. I would hesitate to say just how many specimens were broken, but I believe at least 1500 concrete cylinders were taken by Mr. Neeld's inspectors from the concrete after it had been placed in the forms. The temperature of the air and of the concrete in the forms was taken throughout the day and all of the data from the tests were carefully recorded. One seldom finds a job in which the construction data have been so well tabulated, and, no doubt, this information may some time be valuable for the use of this Society.

Mr. Harvey did not mention the mix of the concrete roadway. It was 1 : 1½ : 3 of cement, local sand, and Ligonier crushed stone. Engineers may wonder why the road was built 11 inches thick at the center and nine inches at the edge; the facts were that Mr. Neeld had completed the design of the roadway just before the publication of reports which indicated that the edges of road slabs should be thicker than the center. Perhaps such a design would not apply in any case to this tunnel.

Referring to the panic in the tunnel, I would say that if people had not insisted on racing their engines and honking their horns they might have kept their heads and they could have walked through the passage ways, which were not over 500 feet apart, directly into the out-bound tunnel and been in pure air. Such an occurrence would not happen again because the police force would now turn the traffic back around the north end of the tunnel and send it back through the out-bound tunnel. At that time the traffic officers were new and did not have the control which they have to-day.

C. H. Dorsey:† It would be interesting to know the method used in driving the tunnels, and the speed attained.

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†Treasurer, R. G. Johnson Co., Pittsburgh.

C. K. Harvey: I would have to refer that to Mr. Frank W. Ritchey, who was Resident Engineer for Mr. Neeld on this work.

Frank W. Ritchey:* The excavation in the Liberty tunnels was practically a full-face operation, leaving about 10 feet of bench back of the heading—just sufficient to erect the steel rings that supported the roof over the new day's work without putting up scaffolding, which was the only reason for leaving the bench. A Marion steam shovel (1½-yard dipper) loaded the material into three-yard, side-dump cars, which were hauled to the tunnel portal by electric motors, from which point steam locomotives took them to the dump in McKinley Park. The shovel was operated by compressed air.

The rate of progress was 12 feet a day in each heading, and the job was so well organized that when the date of reaching a certain point was figured some three or four months ahead it checked within one day.

The excavation was made down to the bottom of the side-wall footings, as it was found to be cheaper to backfill to the roadway subgrade than to dig trenches for the side walls.

The concrete was 1 : 2 : 4 mix of "Alpha" cement, sand, and gravel, except that the footings of the Sawmill Run bridge were 1 : 2½ : 5 of the same materials, and the roadway, curbs, sidewalks, and parapet walls were 1 : 1½ : 3 of "Alpha" cement, sand, and Ligonier chips.

A mixing plant was located at each end of the tunnel, and the concrete was hauled to the forms in steel hoppers, dumped into bins, and placed in the forms with shovels in the case of the footings and side walls. For the arch, it was dumped into a blower and forced into the forms by compressed air. The footings were kept about 100 feet back of the face of the heading, the side walls 50 feet back of the footings, and the arch 50 feet back of the side walls, so that the completed concrete was within about 200 feet of the face of the heading all the way through. At the start, excavation was carried in about 750 feet without concrete, until it was found that some of the beams were beginning to sag, when excavation was stopped and concrete was carried in to about 100 feet from the face, and from that time on

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there was never any part of the excavation exposed for more than 30 days before being filled with concrete.

W. E. FOHL: What was the nature of the temporary supports you used ahead of the concrete?

FRANK W. RITCHEY: The roof support consisted of eight-inch, H-beam, seven-segment, steel rings, each segment being approximately seven feet in length. These were placed at six-foot intervals on 12 by 12, hardwood wall plates, set about three feet above the springing-line of the arch. Three-inch lagging was placed outside of these rings and the remaining space was packed with rock as tightly as was possible by hand. Two-inch pipes were placed in the forms, running up through the lagging, and after the arch concrete was thoroughly set, grout was blown through these pipes until the entire backing was sealed up and all voids filled.

P. W. PRICE:* In about what percentage of the length of the two tunnels did you have to use posts to support the arch ribs?

FRANK W. RITCHEY: It was found necessary to use plumb posts under the wall plates for approximately 50 per cent. of the length of the tunnel. These varied in length anywhere from a foot to the whole depth of the excavation.

J. M. RICE:† Did you encounter any water?

FRANK W. RITCHEY: Very little water was encountered.

WINTERS HAYDOCK:‡ What kind of roof did you have, and what percentage of breakage?

FRANK W. RITCHEY: The average overbreakage was 0.8 of a foot, though there were a few places where it reached five or six feet.

C. H. DORSEY: How was the drilling done?

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†Consulting Engineer, Ptitsburgh.

‡Chief Engineer, Transit Commission, Pittsburgh.

Frank W. Ritchey: The drills used were jack hammers, operated without water. In the early days, before any concrete was in place, levels were taken periodically on the centers of the key segments and at each joint in the steel roof supports, in order to ascertain the amount of settlement taking place. This settlement was not uniform throughout the ring, occurring in the crown or on either haunch, governed by the nature of the material overhead, and generally amounted to 0.10 to 0.15 of a foot. The joints were not milled and were bolted together with two web splice plates and a bent plate on the bottom of the flange, allowing considerable play in each joint, and enabling the ring to conform in shape to the amount of pressure exerted upon it.

Winters Haydock: How long were the sections of forms for concreting?

Frank W. Ritchey: The footing forms were built of wood. The side wall and arch forms were Blaw-Knox steel forms and were 24 feet in length in the headings from the south end and 20 feet in length in the headings from the north end.

Forms were left in place 24 hours after the concrete was poured. The forms, being 24 feet long, covered two days' advance in excavation. A form was filled one night, allowed to stand the next day and night, and moved forward on the second day for another pour on the second night.

N. F. Hopkins:* When was the drilling done?

Frank W. Ritchey: Drilling and concreting were done at night, and bracing, mucking, and form setting in daytime. The men were paid for 11 hours, but when they completed their 12 feet of work they were through. The day shift was frequently out by 3 p. m. and the night shift generally finished at about 4 a. m.

The faces in the two headings were kept very nearly abreast of each other, there being not more than 50 or 60 feet between them. Center-lines, carried from the two ends of the tunnel, were 0.03 of a foot apart where the headings met. The ventilation shafts, 200 feet deep, were 0.10 of a foot off the tunnels.

*Civil and Mining Engineer, Harrop & Hopkins, Pittsburgh.

C. H. Dorsey: I believe they tried to use a mucking machine, but they gave it up.

Frank W. Ritchey: A mucking machine was purchased and delivered at the job, but as the bench idea was quickly abandoned it was never taken into the tunnel.

An attempt was made to apply membrane waterproofing to the inside of the lagging in the portal arches, but, as it was found impossible to get the surface dry, the membrane would not adhere, and this form of waterproofing had to be abandoned. Both portals were more or less damp, especially the south portal, above which an embankment of the Pittsburgh Railways Company formed a pond without providing an outlet.

Emil Hallgren:* Suppose that the excavators had struck extensive pockets of sand or gravel, which would not sustain itself, but swamp or fill the inner end of excavation, would you have been prepared for this? I know of one case, especially, where a small tunnel had to go through a large sand hill. A method of freezing each successive section ahead was employed, when the frozen mass was cut into and a section of brick-arch lining built, thus completing the tunnel. In your case, it would have been impossible to use concrete, if the freezing method had been employed, as the frost would badly interfere with the setting of the cement.

Frank W. Ritchey: No provision was made for handling unusually soft or sliding material because the geological formation did not warrant any expectation of that nature. In sinking one of the shafts an old coal-mine was encountered, but it was in cold weather, and it froze naturally and remained frozen until the shaft lining was in place.

C. H. Dorsey: What means of ventilation was used in driving?

Frank W. Ritchey: During the construction period it was not found necessary to install an artificial ventilation plant, as the exhaust air from the drills and the shovel was sufficient to keep the air

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fresh. Occasionally an air valve would be opened to accelerate the clearing of dust or smoke. The shots were fired about 4 a. m. and the day shift went in at 7 a. m., which allowed plenty of time for the air to clear.

There is a cross passage between the tunnels every 500 feet, but these are not for ventilation purposes, but simply allow passage from one tube to the other in case of necessity. These passages are closed by an iron door at each end, which is kept locked, but is provided with a pane of glass which in case of necessity can be broken in order to unlock the door.

N. F. Hopkins: As I understood the speaker, there is an excess of air coming in the tunnels above what is drawn in by the fans. Am I correct in that?

R. H. Helick:* There is a small amount, sufficient to keep the air pure, but not very much.

V. R. Covell: Mr. Helick has been close to the operation of the shaft, and he might be able to give us some interesting information on that.

R. H. Helick: After the tunnels were finished they were waterproofed by grouting, as Mr. Ritchey has told us, and the shafts were also grouted. Booth & Flinn, Ltd., had given a bond to keep the tunnels dry for a year after they were turned over to the county, and at the end of the year they were notified that additional grouting was necessary. They spent most of the winter of 1924-1925 working with a small gang, and left the tubes quite dry. Since that time, leaks have developed again, chiefly at construction joints. I believe it is not possible to build a large structure like that of concrete and make it absolutely dry. We can say, however, it is for all practical purposes a dry job.

The leakage in the exhaust shafts freezes in extremely cold weather. During the winter of 1924-1925, we were much surprised to find ice forming in dangerous quantities in these shafts, and in one instance a mass fell on a truck, narrowly missing the driver. We

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placed temporary timbering to support a screen of subway grating for the protection of traffic. Last summer permanent steel supports were built into the lower ends of the shafts, and the subway grating is now on these supports, which include spiral springs to break the shock of falling ice or spalled concrete. So far no concrete has come loose.

We still have some trouble with water trickling through the gratings and forming icicles below them, but constant inspection in cold weather serves to keep this danger at a minimum. It is interesting to note that before we got screens placed it was the practice of the tunnel force to shoot down the ice masses with a rifle. Of course this was done with proper precautions against endangering traffic.

There are several other things to be noted. One is the necessity for heat in the fan house. This was unforeseen, but has been temporarily remedied by placing gas stoves. The trouble was that warm, moist air striking the machinery chilled from a previous cold spell would condense on it. This was particularly bad for the electrical equipment. Also there was trouble with the lubrication in cold weather. Some day we hope to have steam heat at this plant.

N. F. Hopkins: Is part of the ice due to the condensation from the air?

R. H. Helick: That was my first thought, but we investigated thoroughly enough to know that is water seeping out through the seams of the concrete.

N. F. Hopkins: What is the water gage on those fans?

R. H. Helick: I do not know. We have no gages on them. We have not done much in the way of testing them, but we know we are getting good ventilation. By the indications of the carbon monoxid recorder we are on the safe side, and that is sufficient for practical operation.

C. K. Harvey: I would like to ask Mr. Helick's opinion as to the proper location of the exhaust ventilating shafts to avoid the danger of falling ice or other material.

R. H. Helick: My idea is that instead of having the shaft open directly into the tunnel, it should be curved at the bottom toward the approaching traffic in such a way that falling objects would be trapped by a cross wall or similar obstruction. This would mean a much more complicated structure, but would be worth the extra cost.

J. M. Rice: This was a rather unique undertaking and it would be very interesting to set down conclusions on points of design that could be improved to get a better design or better operation. I trust it would not be out of place to ask the men responsible for this work to tell us some of these. I think the paper could be made more valuable if this information were added.

R. H. Helick: There are no sewers or catch basins in the tunnels, and water getting into them must travel their entire length of 5889 feet. Since a great quantity of dust accumulates all over the interior of the tunnels it has been the practice to wash them down with fire hose. Sewers and catch basins would greatly aid this work. There are water connections throughout the tunnels. The dust mentioned above coats the interiors of the tunnels a uniform gray, and it is difficult at times to estimate distances. Painting the hand-rails and curbs helps, especially if the latter are painted black on their vertical faces.

The lighting is not quite perfect, as alternate zones of light and shadow are thrown on the walls. It has been suggested that this helps to estimate distance, but an improvement could no doubt be made by spacing the lamps 35 feet on centers instead of the present 50-foot spacing. Reflectors tilted forward would also help. The new tunnels at Tenth Street will incorporate these improvements.

N. F. Hopkins: What is the velocity of the air?

R. H. Helick: We have not been making any theoretical check, as I said a while ago. I suppose Mr. Neeld has some figures, but we have not given it any attention in a scientific way.

P. W. Price: Has anybody made a check of traffic to relate the cost to the traffic borne, giving a unit of cost?

R. H. Helick: That would be interesting, but we have not done it. We know in a general way when our peak-loads occur. Sunday evening is the busiest time in the tunnels, as far as the number of vehicles is concerned. The heaviest traffic through the week is made up of trucks. We do not know what the relation is between traffic and the cost of ventilation. Generally speaking, the slow traffic keeps to the right and the faster passes on the left. This has been a hard winter on all kinds of paving. Everybody has used chains practically all winter. While the streets are blanketed to some extent by snow and ice, the tunnel floor is not, and of course it gets the full action of chain wear; and on the right-hand side, where the slow traffic runs, the wear is the most apparent. That is where the heavy traffic goes with the big chains. I think it will not be very long until we will have to resurface.

Emil Hallgren: In regard to the ventilating stacks, would it not have been practicable to combine the four single-flue stacks into two double-flue ones, and place these centrally between the two tunnels, the flues on each side being properly connected to the upper arch portion of each respective tunnel, for the inlet or outlet to the fans above. At the base of the stacks the flues could extend down below the side connections to the tunnels, thus forming storage pockets for ice, etc., which could be removed through a door alongside a cross tunnel through the division wall. This would eliminate the danger of dropping ice from the top of the tunnels. It is easy for any critic to use the "aftersight" of the pioneer engineers and builders for his own "foresight," as I am sure that Mr. A. D. Neeld would have provided for all emergencies could they have been foreseen. I would also recommend these double stacks to be circular in cross-section with a diametrical division wall, which lends itself better to securing a waterproof inner lining, besides being considerably cheaper in excavation and materials.

R. H. Helick: That is a question of design with which I am not familiar. I was not in touch with the original design at all. You would have to put a curved passageway from the shaft to the tunnel. My idea was that the curved shaft should open into the roof of the tunnel toward the direction of traffic. The New York tubes, I believe, are being ventilated by cross currents of air.

P. W. PRICE: I should like to hear an expression from any one present as to the use of gunite in waterproofing or protecting soft rock surfaces in tunnels and cuts. I have in mind not only the use of gunite for waterproofing seams and protecting soft shales that go to pieces rapidly upon exposure to air in tunnels in advance of placing a permanent lining, but also the use of gunite for the same purpose in rock cuts where, if placed promptly and in sufficient amounts, it might enable soft rock slopes to stand indefinitely at a steeper slope than otherwise. This would frequently mean bonding the gunite by means of keys dug in the rock for that purpose and, of course, a certain amount of mesh or rod reinforcement to prevent temperature cracks.

I also wonder if gunite might not be substituted for loose rock packing behind the arch ribs in tunnel work. While it would certainly cost more in the beginning, could it not be handled about as rapidly as the placing of the ordinary packing? If so, it should eliminate the final use of grout under pressure, except in exceptional cases. The cost of the gunite could therefore be charged against the cost of the pressure grouting usually required before the tunnel is completed. Where there is considerable breakage above the arch rib, a combination of gunite and loose rock packing would naturally suggest itself and would undoubtedly give a more waterproof job than depending upon the grout completely filling all the voids left in the loose rock packing.

J. M. RICE: I know gunite is very, very effective in covering an old reservoir and waterproofing it, so I would presume from this that it would be effective with a tunnel.

N. F. HOPKINS: This tunnel is of a great deal of interest viewed as an engineering feat—that is, as a piece of construction to be accomplished—and the builders deserve great credit for carrying the work through so successfully. It is a question whether the tunnel can be regarded as an economic success. Here is six million dollars used in the construction of a hole through the hill between two ravines. A resident of Mt. Washington still has to climb the hill to get from Sawmill Run valley to his home. Could he not have done the same climbing from the Monongahela valley if a roadway costing one-tenth as much as the tunnel had been constructed from the South Side to

the top of the hill? Of course, the tunnel enthusiast will say that the increased valuation on the South Hills will pay for the tunnel, losing sight of the fact that the increased development in the South Hills is made at the expense of other sections of the county that do not require a $10,000,000 tunnel to develop them. Apparently, the county authorities had the money to spend and wanted to spend it. Engineers seem prone to think of construction and mechanical problems, forgetting the economic features.

A great deal of "nonsense" is indulged in as to traffic schemes making a town. It is business that makes a town, and one thing that drives business away from a town is high taxation. The extravagant construction programs of the city and county have caused a great increase in taxes. No commensurate increase in the business growth of Pittsburgh and Allegheny County has taken place, and now the Chamber of Commerce and other civic bodies are awakening to the fact and making efforts to "promote the progress of Pittsburgh," finally realizing that Pittsburgh can not "promote progress" when handicapped by high taxation and unsound economic programs.

SUPERPOWER, THE GIANT KILLER*

R. F. Schuchardt†

When the interesting invitation from your officers came to me to address this organization meeting, marking the co-operative efforts of two great societies, I wondered what subject I might talk about which would be most fitting for the occasion. Having decided this, I remembered a statement of a famous diplomat that words were created to express thoughts—and to conceal them. I needed a title that would effectively conceal my subject in order to avoid the possibility of a slim attendance to-night. The words chosen and printed in the announcement do not in this instance carry the meaning which most of you probably give them in your own minds.

In selecting superpower as part of the title I did so with the memory of a talk I had the privilege of giving in this city on that subject three years ago, in spite of which, however, you have invited me to come again. Superpower, as I am using it in this title, represents my conception of what the true engineer is—an individual having certain power beyond that of the average man because of his special education and training and the resultant ability to analyze and to think logically.

The giant in my picture is an ogre and the symbol of all those things that should not be—sand in the bearings of the wheels of progress, ignorance, greed, worshippers of Mammon, and all those forces which, while they permit us to dream of ideals, make it very difficult to realize them. But we grow by surmounting difficulties, as Epictetus stated so long ago.

The engineer, as you know, has been hailed during this past decade as the savior of mankind, the hope of the world to-day. His work certainly is responsible for making life richer and better.

Think of the day when the first white man, La Salle, saw what is now Pittsburgh. That was in the latter half of the seventeenth century, when Louis XIV was making France the wealthiest and most powerful nation of the world. At that time the printing press had been helping to spread knowledge for over two centuries. The new

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astronomy of Copernicus and that epoch-making demonstration of Galileo from the Leaning Tower of Pisa had revolutionized men's thinking some time before. The Italian Renaissance, marking Europe's emergence from chaos, superstition, and ignorance, and giving the impulse to the renascence of western civilization, had shed its light for more than a hundred and fifty years. Louis had built his Versailles with the magnificent palace and wonderful gardens, yet the Grand Monarch himself with all his magnificence and power, and in spite of the learning and advance of that awakened age, enjoyed few of the comforts and conveniences that are the possession of the humble worker in Pittsburgh to-day.

What has happened since that time to advance civilization to the state in which we know it to-day? You will readily agree when I say principally engineering. It is the work of the engineer primarily that has worked the transformation. Without the engineering progress of the past centuries, Pittsburgh would to-day be much as when La Salle saw this place in 1669.

Fundamentally, the engineer has reduced the amount of human effort required to perform tasks and has developed materials and with them has built machines to do what formerly was impossible for human hands. His works speak eloquently for him—monumental structures, power-plants, intricate machinery, great hydraulic works, widespread transportation systems, ships, automobiles, telephones, radio, airplanes, submarines, chemical processes, electrical devices for the home, and so on.

America with its encouragement of individual initiative and its opportunities for the development of talent has made the most progress of any country, with the result that it to-day enjoys the highest standard of living in the entire world. Each worker in the United States has an average of about 3.3 horse-power of machinery to help him produce. This is nearly twice that of England and four times that of Japan. In China, with practically no power, the worker's life is one of intense drudgery. The average wage scales, and therefore the purchasing power, for these countries are in about the same proportion. Viscount Rothmere, publisher of the London *Daily Mail*, recently suggested that we loan his country one of our industrial leaders to help England back to prosperity.

With increased industrial production a larger population can be

supported. Since 1850 the population of the world has increased 60 per cent., and that of the United States 350 per cent., and with it have come the better living conditions just mentioned. The average person to-day has six times as much manufactured goods as his grandfather had in 1850.

The first great advance of modern times came, as you know, with the steam-engine somewhat over a century ago, but the advent of electricity greatly accelerated progress, and particularly since the opening of the twentieth century. The electrical engineer has had the opportunity to make the greatest contribution of all and he will continue to do so since scientific research seems to disclose more and more that electricity is at the bottom of everything. Certainly the industrial world to-day is on the basis of electric power.

Herbert Hoover has called electricity man's greatest tool. Others have named it "the greatest accelerator of production and most helpful burden bearer introduced by engineers to modern civilization." Electricity is admittedly the greatest labor saver and it is by building on this fact that the engineer is bringing about our higher standard of living.

The abundance of electricity, which is being brought to an ever-increasing number through the spread of what has come to be generally known as superpower, is, of course, not the work of the electrical engineer alone. The mechanical engineer, the civil engineer, and even the chemical engineer, each has his important part. In speaking of the work of electrical engineers I am not unmindful of the great contribution to our social and industrial life made by the telephone and the radio, and how in the 50 years since its invention 27,000,000 telephones have been put into use in the world, with the United States having 17,000,000, or an average of one for every one and a half families; but since my experience has been in the power field I naturally refer more to that, as this is staying on familiar ground for me.

So let me call your attention to the great conservation of our coal and our financial resources that the central-station engineer has brought about. The reduction from an average of about eight pounds of coal per kilowatt-hour in the United States in 1900 to about two pounds in 1925 has saved the nation hundreds of millions of tons of coal, while the designer of the central-station system is to-day making one dollar do what it took two much more valuable dollars to do

before 1910. A measure of the results can be had from the following data: In 1902 the per capita electricity production from central-stations in the United States was 60 kilowatt-hours; in 1912, 185; in 1922, 436; and in 1925, 580. For Chicago the 1925 figure is 1030; for New York (including production for the electrified steam road terminals), 870; for Pittsburgh I understand it is about 900.

This is but one of the accomplishments that have been brought about by the engineer. To mention other important ones would be but to repeat the list given earlier as the works which speak so eloquently for him.

A recitation of these deeds seems almost to mark the engineer as a superman with talents that set him quite apart from his fellows. Of course, he is just common clay as all the rest of mankind, but his education and his experience have taught him a line of attack which has brought about these results. As he is trained to think things out and get at the facts, he knows he must deal truthfully with the facts if he would succeed. His field is the whole range of natural forces, and by wresting scientific truths from nature and turning them to man's benefit he has entirely changed the art of living, bringing greater richness and fullness into our lives.

Some years ago there was much talk about the engineer not being sufficiently recognized (which was largely his own fault), but this seems now to be changing. To-day his capacity for leadership is being recognized increasingly by appointment to executive positions and in other ways.

Now, having enjoyed these self-bestowed bouquets and having basked in the sunshine of our own praise, let us, like real engineers, ask ourselves candidly if this is all true. If others think us the hope of the world, are we worthy of that confidence? Let us frankly analyze ourselves as a group. Let us see if we are just trained technicians held close to the line because we can not, like the doctors, bury our mistakes; or are we members of society with an appreciation of the part that is expected of us.

The engineer should individually be much more of a factor for progress in non-engineering fields than he ordinarily is. If there are any in the audience who are participating to the limit of their opportunities in movements of community interest, political or otherwise,

or in national movements, and I am sure there are many such, the following remarks do not apply to them.

I am reminded here of an old political war-horse of years ago. In my school-days I enjoyed going to political meetings, and at one of these I heard a great spread-eagle address, such as were common in the early nineties. The orator seemed to take particular delight in receiving evidences of disapproval from his audience. This was the signal for him to step forward to the edge of the platform and, with uplifted arm and a look toward the objector, say with emphasis, "I am glad to get this evidence from you, for it justifies the effort I am making; for I come not to bring the righteous, but sinners, to repentance."

We do hear of occasional instances of engineers acknowledging their special obligations. Herbert Hoover is a conspicuous example, and there are scores of others in lesser fields. I fear, however, that as a class engineers have not yet grown to full stature as citizens applying their talents to matters of general civic interest. At times it even seems that, in connection with public questions, engineers are not using logical minds at all. Their work with the forces of nature ought to teach them that all actions are governed by law. Their power of analysis should help them to understand that the laws of human behavior (I don't mean the man-made laws) are just as inflexible as the so-called laws of nature—all are the laws of cosmos, and we call them God. God's laws are very real. To obey them fully is to be in harmony with the Infinite, and that leads to a successful life. Violation of these laws brings distress, retrogression, confusion, and absence of happiness. The most fundamental social law is known as the Golden Rule. Empires have fallen in ancient days and in modern because their rulers violated it, just as structures crumble when nature's laws have not been observed in their construction.

The engineer should also find much guidance for every-day application in a study of history. The struggles of our forefathers in fields political have given to us heritages as rich as those of the scientists on which we have built our present engineering knowledge. These should encourage us to keep on striving and not lose heart if results seem to be pitifully meager.

All of this seems to be dealing in glittering generalities. How, specifically, can the engineer be of particular service to his fellows out-

side of his professional field? Let us look at this in terms of his community, his state, his country, and the world.

First, the community or city. Much of city government is engineering. City planning, urban transportation, traffic terminals, municipal improvements, public utilities, smoke abatement, water and sewerage, highways, bridges, etc.—all are engineering.

There is another special obligation imposed on the engineer by the fact that the improvements in machinery, in rapid transit, in building construction, in electrical development are all the work of the engineer, and these, while they have added immeasurably to the general welfare and comfort, have brought the rural population into the cities in such numbers as to result in fearful congestion. The engineer should aid actively and intelligently in solving the problems thus created. The answer lies largely in a saner development of the city and in greater decentralization of population.

What is actually happening in our cities—if not with the engineer's co-operation, at least with his passive consent? With the mistaken notion that speed, and more speed, and still more speed makes for a happier life, for a better civilization, and that vertical transportation is speedier than horizontal, we put floor upon floor with buildings reaching proudly into the sky—literally piling Ossa on Pelion to attain the objective of business convenience. What thought is given to the inhabitants of the lower floors who are often robbed of the health-giving sunlight for a large part of the day, or to the resulting deep cañons now so abundantly filled with the exhaust from motor-cars? Nor does the relative capacity of the street to the population of these office boxes seem to enter into the calculations.

That there is at least a partial awakening is evidenced by the set-back requirements of tall buildings, but that is only a slight palliative. The complicated traffic problems are being met by the engineer by providing more transportation facilities. There is not enough room on the surface, so subways are dug to carry the human units of the commercial and industrial machine back and forth. Again, these are overcrowded and one, then two, and then three or more street levels are proposed.

Though the sky-scrapers may be the most beautiful that our best architects can design—and they are often far from being that—their

fine lines and decorations are lost in their crowded setting, and how void of beauty then are the surroundings of our business life.

What mechanical cities this all means and what a mechanical life for our children! Is that the kind of a civilization engineers want to see built? The creator of the Robots in drama must have had a vision of this.

What can we do to be saved? as Billy Sunday would say. You have a very potent means right here in your engineering organization. Undoubtedly you are using it. By studying these civic problems here in your Engineers' Society, and by applying your special abilities to the solution of them, you not only discharge a debt to your community, but incidentally you improve the regard in which the engineer is held both socially and politically. A proper, active participation in the political life of your community can reflect only credit on the profession.

We now come to the state. There are, of course, many matters of state-wide importance in relation to which engineers could give intelligent aid—projects such as highways, canals, and public-utility regulation. There is another problem which has been brought before the public here in Pennsylvania which you probably expect me to refer to. Some of you may think that I had it in mind when I chose my title, and possibly I did.

I would not have you think, however, that I consider your Governor's Giant Power an ogre. It is somewhat too pathetic for that. I would rather believe that the report of a year ago represents a sincere effort to be of service to the people of your state. Unfortunately for real progress, the framer of the report has a stronger social sense than an economic one and this has led him into grievous economic error. Observance of the laws of economics, also, is necessary for human welfare. Had a clearer view been brought to bear, it would have been recognized that the social objective is more quickly and more surely gained by co-operation and regulation.

I shall not discuss the Giant Power report in detail. Your own engineers have subjected it to the test of cold logic and you are familiar with the weaknesses which they pointed out in it. I do, however, want to say a few words about the "wild elephant." Let me refresh your memory by reading a paragraph from the message with which your Governor transmitted the report:

"Giant power and superpower are as different as a tame elephant and a wild one. One is the friend and fellow-worker of man—the other, at large and uncontrolled, may be a dangerous enemy. The place for the public is on the neck of the elephant, guiding its movements, not on the ground helpless under its knees."

This picturesque reference to the menagerie and the jungle does not excite me. I recognize the fact that when men live in a political atmosphere rhetoric is sometimes thought the equivalent of logic. Right here is where engineers should function. They should analyze statements of public officials and attempt to ascertain through the analysis what are the facts.

Let us see how dangerous an enemy this elephant is and how unmercifully the public is being ground under its knees. The record of the past ought to give a fair index of what to expect in the future. You have already been reminded that great saving in coal and money has resulted from the progressive work of the electric-utility companies, and the increasing use of the companies' product has been referred to as largely responsible for our social advance.

The elephant has grown from a capitalization of less than half a billion dollars at the beginning of the century to over seven billion dollars to-day, for the light and power systems alone. The capacity of the plants of all public-utility companies was one kilowatt per 33 inhabitants in 1900, and is to-day one kilowatt for each 4.8 people of the country (about one kilowatt per family), or a total of about 24,000,000 kilowatts in public-utility plants. These are indeed colossal figures. Let us see what they mean in human terms. The seven billion dollars represent the invested savings of nearly three million of your and my fellow-citizens of the United States—a pretty good form of public ownership, isn't it? The output of approximately sixty-six billion kilowatt-hours in 1925 was enjoyed by eighty million people. Think of it—the great benefits of electricity, the comforts and conveniences, the cleanliness of its work, and the banishment of drudgery brought to nearly three-fourths of our population through the initiative, the skill, and the boldness of those who manage and who build these elephantine systems! And the industry is still young. Though the United States of America has only 6½ per cent. of the world's population, it has a greater production of electricity than all the rest of the world combined. We are the envy of European visitors, and

especially of engineer visitors who know the reason for our commanding position. In England, where a major portion of the elephant is "tamed" and works in government harness, the per capita generation of electricity is about 180 kilowatt-hours, compared with 580 for the United States. The British technical press devotes considerable space to what America is doing, and it is saying to the industry at home, "Go thou and do likewise." There is to-day a labor commission from England visiting America to learn how it is done. It is not an accident that the average rates for electricity during the last dozen years have dropped nearly nine per cent. in the face of a rise of about 70 per cent. in the general cost of living.

The hydro-electric system of Ontario is frequently cited as an illustration of an obedient, well-trained elephant. There the rates are lowest where the votes are highest. That's politics, not economics. The engineer who looks into facts will learn that the much-advertised rural rates in Ontario are actually 30 to 50 per cent. higher than similar rates of the Pacific Gas and Electric Company of California. They were when I last compared them, nearly two years ago, and I have read of several discussions in Ontario indicating that the Canadian rates must be increased. Isn't it strange, if these rates make life so attractive up there, that farmers should migrate to the good old U. S. A. at the rate of considerably over 100,000 per year, as has happened in the last few years?

Water-power development is another subject regarding which much misinformation is spread. This is too large a subject to go into at this time, but engineers owe it to themselves to have an understanding of the facts. For instance, they should know the difference between Niagara Falls with about 1,000,000 kilowatts developed from roughly one-fourth of the stream, but with a wonderfully steady flow because of the great reservoirs; and Muscle Shoals, where the Tennessee River has a variation of 54 to 1 from extreme flood to minimum flow. With the present installation—that is, without expensive dams for storage reservoirs—the "firm" capacity of the Wilson Dam plant is just equal to a single unit in the Colfax power-station of the Duquesne Light Company; that is, 60,000 kilowatts. Water-power development is a very complicated subject, but engineers should not allow the public to be misled by false information.

Engineers should be familiar with at least the fundamentals of

all the subjects of which I have just touched a few of the high spots. Pittsburgh is in the midst of one of the really important superpower regions of the country, and you here—all of you—should give thought to the problems involved. An abundant and reliable power supply attracts industries and brings wealth to the state. Widespread interconnections bring to a large number the benefits of the best stations and offset the higher cost of to-day's new equipment, thus tending to keep the cost of electricity from rising. They are also the most potent influence helping the movement looking toward the decentralization of our cities. Engineers should be leaders in insisting that the public problems related to this subject are sanely considered and understood.

And now we come to our country. The English poet, William Watson, once wrote:

> "The ever-lustrous name of patriot
> To no man be denied because he saw
> Where in his country's wholeness lay the flaw,
> Where, on her whiteness, the unseemly blot."

This is not quoted to suggest that there are any particularly prominent blots on the fair whiteness of our country. We all know, however, that the body politic is far from the ideal we all wish it to be. It should be instinctive with the engineer to look for the reason. Perhaps as a class we would at once say "too many lawyers in office." If this is a reason, whose fault is it that there are not more engineers close to the helm of the ship of state? But even out of office there is much opportunity. Public problems are seldom presented without bias. Would this condition prevail if engineers, individually and through organizations such as yours, were to turn the piercing searchlight of their logic on these problems? Some of the problems I referred to in relation to the engineer and his state apply with even more force here.

There is a challenge to the engineer in Macauley's statement, made in 1840: "The test of the success of democratic institutions will come when cheap lands are gone and when that outlet for the pressure of a growing population is no longer open. As for America, I appeal to the twentieth century." How many of the 200,000 of America's engineers are visioning the future through the picture of to-day and are helping to steer that future in the right channel? Our responsibility is a heavy one, but I have faith it will be met.

A large part of this responsibility is to help give proper direction to those who in the years to come will be the engineering leaders. Large men, broad gaged, and with clear vision, will be needed in increasing numbers. Are we really doing all we ought to help develop the vision of these coming men? Does our contact with the young men who find themselves at the threshold of an engineering future fill them with enthusiasm over the opportunities for service offered through the profession, or do we dampen their youthful ardor by reflecting only the hard work and the long hours that alone lead to success? And what are we doing to help our educators give a sound and inspiring start to the embryo engineers?

This brings us to the last—to the engineer and the world. Much that has been said in the sections relating to the community, to the state, and to the country, of course applies here also. Wrong economic thinking is still prevalent and, with the social and economic earthquake of the war in the near background, right thinking is of extreme importance. The history of the Renaissance in the fifteenth century, as of all similar epochs, emphasizes the effect of men's thinking on the conduct of individuals and of nations. The engineers of the world are the hope of the future, but the hope will be realized only to the extent that they make clear thinking prevail.

International boundary lines, with their separate hates and jealousies and ambitions on either side of them, can present no barrier to engineering attainments. As his work in transportation, in telephony, and radio make all the world one, so should the engineer's thinking, influencing that of his fellows, dominate and bring nations together in a spirit of brotherhood.

The success of civilization is not measured primarily by accumulated wealth, but by human well-being; and well-being does not thrive in an atmosphere of ignorance, intolerance, jealousy, and economic error. The engineers, typifying the spirit of service, and with a clear view based on an understanding of all of God's immutable laws, have here a great opportunity. If they are equal to it a grateful world will hail them as being truly

> "Souls tempered with fire
> Fervent, heroic and good
> Helpers and friends of mankind."

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Wm. Penn Hotel, Tuesday, May 18th, at 4:05 P. M. President Wm. E. Fohl presiding, Messrs. Hunter, Goodspeed, Weldin, Eavenson, Edgar, Hopkins, Shaw, Covell, Rice, Humphrey and the Secretary being present.

The Minutes of the last regular meeting held April 20th were approved without reading.

Applications for membership from the following gentlemen, having been published to the Society, pursuant to the action of the Board, were elected to membership.

MEMBERS

Dake, Walter M. — McCune, William H.
Dibble, Robert Horace — Strickler, Elmer V.

ASSOCIATE MEMBERS

Elwell, G. Randolph — Rigdon, C. Reade
Latimer, George B. — Saurbrey, Alexis
Williams, Frank Way

ASSOCIATE

Orr, Ralph Vincent

JUNIORS

Dodworth, James Russell, Jr. — Hale, William Thurber
Odell, John Dwight

Applications for membership were received from the following gentlemen and their names ordered published to the Society. Assignment to the various grades of membership is as follows:

MEMBERS

Brown, George N. — McGannon, Frank Edward
Howe, William C. — Sheets, George DeWitt
Marsh, Burton Wallace — Star, Clarence T.

ASSOCIATE MEMBERS

Guthrie, James McMurchie — Hinderer, Howard L.
Huber, Louis Steele

The following members of the Illuminating Engineering Society have made application for membership in connection with the formation of an Illuminating Engineers' Section of the Society.

MEMBERS

Hoeveler, John A. — Wood, Douglass

ASSOCIATE MEMBERS

Allen, James G. — Bowers, Jaul E.
Bamborough, M. A. — Kiefer, Lewis J.
King, Floyd E.

Application for reinstatement was received from Mr. Joseph T. Miller and after discussion, the Secretary was requested to advise him that he was reinstated to membership.

Application for transfer was received from Mr. D. M. Simons and he was ordered transferred to the grade of Member.

The report of the Secretary showing the financial condition of the Society at the close of business April 30th, having been audited by the Finance Committee, was approved.

Mr. Weldin, Chairman of the House Committee, reported an evening attendance in the Club Rooms of 467 for the month of April.

The Secretary reported in the absence of Mr. Affelder, Chairman of the Membership Committee, that a meeting of the Committee had been held to go over the applications received since the last meeting of the Board and assign them to the various grades of membership.

Mr. Goodspeed, Chairman of the Publication Committee, reported that his committee had held one meeting and that a tentative program for the year had been outlined. The Committee expects to hold another meeting within the next few weeks, when final program will be passed upon.

The Secretary called attention to action taken at the regular meeting of the Civil Section, March 2nd, at which time Mr. Davis as Chairman of a special committee on Local Aggregates for Concrete, presented a report in which the committee included the following recommendations—

"This committee desires to recommend that a Fellowship be established for the year 1926-27 at the Carnegie Institute of Technology to be filled by a properly qualified young man who will make a study of any or all of these problems. This Fellowship might be on a half-time basis or on a full-time basis. If on a half-time basis, the holder of the Fellowship might also qualify for the degree of Master of Science in Civil Engineering.

The Committee further recommends that the Fellowship be financed by the aggregate producers, cement companies, contractors and others in the district who are interested or who would profit by the results of the investigation. The amount required would vary from about seven hundred and fifty dollars to fourteen hundred dollars, depending upon whether the holder of the Fellowship was on a half-time or full-time basis. The Institute will furnish, without charge, its laboratories and laboratory equipment."

It was regularly moved and carried that this recommendation be referred to the Board of Direction for their consideration and action. The Secretary stated further that he had received a letter from Mr. Davis in which he stated that at a meeting of his committee on Friday, May 14th, this matter was again brought up for discussion and the committee, by resolution expressed itself as favoring the Fellowship at the Carnegie Institute of Technology on the Fall term basis and urged that the Board of Direction take action as early as possible. He stated that the Committee had considered the possibility of establishing this Fellowship at the Mellon Institute, but had come to the conclusion that it would be more practicable to have the work done at the Carnegie Institute of Technology. The committee further urged that plans for the Fellowship be so worked out that actual work may be started at the beginning of the Fall term this year. In order to do this, and make a careful selection of a man for this Fellowship, the selection should be made before the close of the present year.

After a general discussion, it was regularly moved and carried that the Board of Direction authorize the establishment of this fellowship and the selection of the man and the financing be placed in the hands of Mr. Covell, Chairman of the Civil Section.

The Secretary read an abstract from the Minutes of the Executive Committee of the Mining Section at a meeting held May 4th, in which attention was called to the question of lack of standardization of mine timbers. It was regularly moved and carried at this meeting that this Section recommend that the Board of Direction authorize the appointment of a committee to formulate standards for mine timbers.

After a discussion, it was regularly moved and carried that the Executive Committee of the Mining Section be authorized to appoint such a Committee.

The Secretary presented, at the request of the President, a statement in regard to a proposed Machine Tool Exhibit to be held in Langley Hall, Carnegie Institute of Technology in the Fall of 1927. The Secretary stated that some weeks ago a meeting had been called of representatives from the Carnegie Institute of Technology, Pittsburgh Section, A. S. M. E., Pittsburgh Chamber of Commerce, and Engineers' Society of Western Pennsylvania, to discuss with representatives from New Haven, the possibility of holding a Machine Tool Exhibit in Pittsburgh, such as is now held at Yale University. The New Haven representatives explained in detail the plan of the organization and operation and stated that their exhibitors had felt that it might be well to alternate between New Haven and a Western city and Pittsburgh had been suggested as a logical place, especially in view of the fact that the Carnegie Institute had ample space in Langley Hall for holding this exhibit and had expressed an interest in it. The exhibition is entirely on a self supporting basis. In fact, the last two years there has been a small surplus.

After a general discussion of the details of the plan, it was regularly moved and carried that this Society cooperate with the Carnegie Institute of Technology, Pittsburgh Chamber of Commerce, Pittsburgh Section A. S. M. E. in holding such an exhibit, if the other organizations approve.

The President called attention to the fact that after the above mentioned meeting, an article had appeared in Iron Age, stating that the Machine Tool Manufacturers' Association planned to hold an exhibit in Cleveland in 1927. Telegrams were sent to New Haven to get particulars of this move, but up to this time no word has been received from them. Mr. Fohl pointed out that there would be some doubt as to whether Pittsburgh would hold an exhibit if one were held in Cleveland.

The Secretary stated that an invitation had been received asking the Society to authorize its Secretary to attend a conference of Local Society Secretaries to be held in Detroit, June 3rd, 4th and 5th, under the auspices of the American Engineering Council. It was regularly moved and carried that the Secretary be authorized to attend the conference.

The meeting adjourned at 5:15 P. M.

K. F. TRESCHOW, *Secretary.*

SPECIAL MEETING BOARD OF DIRECTION

A special meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, Wednesday, May 12th, at 4:30 P. M. President W. E. Fohl presiding, Messrs. Ladd, Hunter, Clifford, Eavenson, Hopkins, Shaw, Covell, Rice and the Secretary being present.

Mr. Fohl stated that the meeting had been called in accordance with action taken by the Board at its meeting of April 20th in which they referred to the Civic Affairs Committee a letter from Mr. C. M. Reppert, Chief Engineer of the Dept. Public Works, City of Pittsburgh, inviting this Society to take active interest in the proposed Bond Issue to be voted on by the people on May 18th. The Civic Affairs Committee was instructed to go into this matter and report back to the Board at a special meeting with recommendation as to what action this Society should take. The President called for the report of the Committee and Mr. H. N. Eavenson, Chairman presented the following:

To the Board of Direction,
Engineers' Society of Western Penna.

Dear Sirs:

In accordance with a request from the Board of Direction at its meeting held April 20th, your Civic Affairs Committee has considered a report on the proposed Bond Issue, submitted by C. M. Reppert, Chief Engineer, Dept. of Public Works, City of Pittsburgh.

While we have not had time to determine whether the estimates submitted are correct we have no doubt that all of the items have been carefully considered and that the personal of this Dept. of Public Works warrants the conclusion that these estimates are correct. We believe further, that the structures and equipment designed are adequate for the purpose intended.

In general, this issue seems to be required to properly maintain our city plant and extend it as the growth of our community requires. It is divided into ten items each of which can be voted upon separately.

The enclosed reference sheet explains the various items proposed in detail and we recommend a careful study of each item by our members and urge upon them the performance of their duties as citizens by voting upon this Bond Issue on May 18th.

Respectfully submitted,

Howard N. Eavenson, Chairman,
Civic Affairs Committee.

After discussion, it was regularly moved and carried that the report be approved.

It was further moved and carried that this report be transmitted to the members of the Society residing in Pittsburgh, with a statement as to the action of the Board in approving it.

The meeting adjourned at 5:15 P. M.

K. F. Treschow, *Secretary.*

CIVIL SECTION

The regular bi-monthly meeting of the Civil Section of the Engineers' Society of Western Pennsylvania was held in the Blue Room, William Penn Hotel, Tuesday, May 4th, at 8:00 P. M. Chairman V. R. Covell presiding, 62 members and visitors being present.

The Minutes of the last meeting held March 2nd were read and approved.

No further business coming before the Section, the paper of the evening on Highway Location and Construction was presented by Mr. S. W. Jackson, Division Engineer, Pennsylvania Department of Highways, Greensburg, Pa.

Written discussion was presented by Samuel Eckels, Asst. Director, Dept. of Public Works, Allegheny County.

The ensuing discussion was participated in by: N. F. Brown, Director, Public Works, Allegheny County; V. R. Covell, Chf. Engr, Bureau of Bridges, Dept. Public Works, Allegheny County; J. P. Leaf, City Engineer and Consulting Engineer, Rochester, Pa.; Samuel Eckels, Asst. Director, Dept. Public Works, Allegheny County; F. W. Preston, Standard Plate Glass Co., Butler, Pa.; Winters Haydock, Chf. Engr, Transit Commission; P. W.

Price, Prin. Asst. Engr, Bureau of Bridges, Dept. Public Works, Allegheny County; Thomas Fitzgerald, V. P. & Gen. Mgr, Pittsburgh Railways Co.; C. B. Stanton, Associate Professor, Civil Engineering, Carnegie Inst. of Technology; and the author.

On motion duly seconded and carried a vote of thanks was extended to Mr. Jackson for his very excellent paper.

The meeting adjourned at 10:00 P. M.

K. F. TRESCHOW, *Secretary.*

REGULAR MONTHLY MEETING

The 439th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held jointly with the Pittsburgh Section of the American Chemical Society on Thursday evening, May 20th in the Carnegie Lecture Hall, Chairman C. J. Rodman presiding, 150 members and visitors being present.

Mr. Rodman announced that due to illness at home, Mr. Fohl, President of the Engineers' Society, was unable to attend the meeting.

It was moved and carried that we dispense with the reading of the Minutes of both organizations and no other business coming before the meeting, the Chairman introduced the speaker of the evening, Dr. E. R. Weidlein, Director, Mellon Institute of Industrial Research, University of Pittsburgh, who spoke on the Reasonable Expectations from Science.

It was moved and carried that a rising vote of thanks be extended to Dr. Weidlein for his very interesting and instructive address.

The meeting adjourned at 10:15 P. M.

K. F. TRESCHOW, *Secretary.*

Vol. 42 JULY 1926 No. 6

PROCEEDINGS

OF THE

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA

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All papers, upon their acceptance by the Publication Committee, become the property of the Society, and it lies within the discretion of the Committee to publish them in whole or in part. The Society, however, does not hold itself responsible for opinions expressed by its members.

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Incorporated 1880

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American Institute of Architects. Journal

American Institute of Electrical Engineers. Journal

American Machinist

American Roofer

American Society of Civil Engineers. Proceedings

American Society of Mechanical Engineers. Journal

American Society of Naval Engineers. Journal

American Welding Society. Journal

Arkitektur

Association of Chinese and American Engineers. Journal

Association of Iron and Steel Electrical Engineers. Journal

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Engineering and Mining Journal

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Engineers and Engineering

Engineers' Club of St. Louis. Journal

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Franklin Institute. Journal

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Great Britain—Patent Office. Illustrated Official Journal

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Institution of Mining Engineers. Transactions

Iowa Engineering Society. Proceedings

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Iron and Coal Trades Review

Iron Trade Review

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ALPHABETICAL ADVERTISING INDEX

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SPECIFICATIONS FOR LOCAL AGGREGATES FOR CONCRETE*

FINE AGGREGATE

1. All fine aggregate shall consist of natural sand or crushed gravel.

2. It shall be clean, with uncoated particles, strong, sound, free from injurious amounts of dust, loam, soft or flaky particles, shale, alkali, organic matter, or other deleterious substances. The amount of coal contained shall not exceed one per cent. by weight.

3. It shall be given the colorimetric test for organic impurities in accordance with the Standard Specifications of the American Society for Testing Materials, Serial Designation C 40-22. This test is recommended as a measure of precaution and not necessarily as one on which to base a rejection.

4. The weight removed by the decantation test, made according to the methods of the American Society for Testing Materials, Serial Designation D 136-22T, shall not exceed three per cent.

5. It shall be of such quality that when made into mortar consisting of one part Portland cement and three parts of dry and rodded sand, by volume, it shall have compressive strengths at the end of seven days and 28 days of not less than that developed by mortar of the same proportions and the same consistency, made at the same time of the same cement and standard Ottawa sand. One bag or 94 pounds of cement shall be taken as one cubic foot. These tests shall be made in accordance with the Tentative Specifications and Tests for Compressive Strength of Portland Cement Mortars of the American Society for Testing Materials, Serial Designation C 9-16T.

6. Fine aggregates shall be divided into two classes, and when tested dry with Tyler standard sieves, the percentage retained on sieves shall be within the following limits, by weight:

Fine sand, suitable for mortar, plaster and concrete	
On a No. 4 sieve	0
On a No. 8 sieve	0 to 15
On a No. 50 sieve	85 to 100
On a No. 100 sieve	94 to 100

*Presented by C. S. Davis, *Chairman*, and adopted by the Engineers' Society of Western Pennsylvania, January 5, 1926. Received for publication February 27, 1926.

Coarse sand, suitable for concrete

On a 3/8-inch sieve	0
On a No. 4 sieve	0 to 15
On a No. 8 sieve	10 to 35
On a No. 50 sieve	70 to 100
On a No. 100 sieve	94 to 100

COARSE AGGREGATE

7. All coarse aggregate shall consist of natural gravel, crushed gravel, crushed stone, or air-cooled blast-furnace slag.

8. It shall be clean, having hard, strong, sound and uncoated pieces, and shall be free from injurious amounts of dust, loam, soft, thin or flaky pieces, shale, alkali, organic matter, or other deleterious substances. The amount of coal contained shall not exceed one-half of one per cent., by weight.

9. Slag shall consist of air-cooled blast-furnace slag of tough, durable pieces, non-glassy in character. Dried slag, when tested according to the methods of the American Society for Testing Materials, Serial Designation C 29-21, shall weigh not less than 70 pounds per cubic foot.

10. Coarse aggregates shall be divided into three classes, and when tested dry with Tyler standard sieves, the percentage retained on sieves shall be within the following limits, by weight:

Small, suitable for reinforced concrete or concrete in thin walls or small volumes

On a 3/4-inch sieve	0 to 5
On a 3/8-inch sieve	30 to 70
On a No. 4 sieve	95 to 100

Medium, suitable for mass or reinforced concrete

On a 1 1/2-inch sieve	0 to 5
On a 3/4-inch sieve	30 to 60
On a 3/8-inch sieve	85 to 100

Large, suitable for mass concrete

On a 2 1/2-inch sieve	0 to 5
On a 1 1/2-inch sieve	15 to 40
On a 3/4-inch sieve	25 to 75
On a 3/8-inch sieve	85 to 100

11. Soundness of coarse aggregate, as used in these specifications, shall mean the degree of resistance to alternate freezing and thawing.

12. Soundness of crushed stone and slag shall be determined by, and meet the requirements of, the method described on page 8 of Bulletin No. 1216 of the United States Department of Agriculture, as follows:

"Immerse 10 small pieces (total weight about 1,000 grams) of the rock in a saturated solution at 70° F. of sodium sulphate (Na_2SO_4) for 20 hours, after which place them for 4 hours in a drying oven maintained at 100° C. Repeat the treatment five times. Note the condition of the rock as to soundness at the end of the test. Samples which exhibit marked checking, cracking or disintegration shall be considered to have failed in this test."

13. Until some generally recognized test for soundness of gravel is available, its soundness shall be determined by the engineer.

14. In highway construction, on account of the abrasive effect of traffic, crushed stone shall pass an abrasion test in accordance with the standard of the American Society for Testing Materials, Serial Designation D 2-08, in which the percentage of wear shall not exceed six; and a toughness test made in accordance with the standard method of test for toughness of rock of the American Society for Testing Materials, Serial Designation D 3-18, in which the number of blows shall not be less than six.

15. Until some generally recognized requirements for abrasion losses of slag and gravel are available, the suitability of such materials shall be determined by the engineer.

C. S. Davis, *Chairman.*

Table I is a comparative statement of the requirements for the grading of fine aggregates under the specifications of the Joint Committee,* the Department of Highways of Pennsylvania, and those proposed by the Committee of the Engineers' Society of Western Pennsylvania. This statement also shows minimum, maximum, and average values for fine aggregates used in Bridge Number Seven, Alle-

*Composed of representatives of the American Society of Civil Engineers, the American Society for Testing Materials, the American Railway Engineering Association, the American Concrete Institute, and the Portland Cement Association.

TABLE I. SPECIFICATION REQUIREMENTS FOR FINE AGGREGATES

Percentage to be retained on Tyler standard sieves

		3/8	No. 4	No. 8	No. 50	No. 100
Joint Committee		..	*a*15	...	70–90	97[d]
Department of Highways of Pennsylvania[c]						
Class A concrete		*a*0	*a*15	...	*b*70	*b*94
Class B concrete		*a*0	*a*15	Not over 5% silt, etc.		
Engineers' Society of Western Pennsylvania						
Fine		..	....	*a*15	*b*85	*b*98
Coarse		..	*a*15	...	*b*70	*b*94
Washington Crossing bridge	Minimum	..	0.0	...	78.0	98.0
	Maximum	..	1.0	...	97.0	99.0
	Average	..	0.4	...	89.1	98.9
Becks Run bridge						
7 cars 0–No. 14	Minimum	..	0.0	...	78.0	98.0
	Maximum	..	1.0	...	97.0	99.0
	Average	..	0.4	...	89.1	98.9
39 cars 0–No. 8	Minimum	..	0.0	...	74.0	97.0
	Maximum	..	2.0	...	98.0	100.0
	Average	..	0.4	...	88.5	98.8
13 cars 0–No. 4	Minimum	..	0.0	...	86.0	98.0
	Maximum	..	12.0	...	97.0	100.0
	Average	..	2.5	...	92.0	99.0
10 cars 0–3/8	Minimum	..	2.0	...	86.0	97.0
	Maximum	..	25.0	...	92.0	99.0
	Average	..	17.2	...	89.5	98.3

a. Not more than.
b. Not less than.
c. Not over 3 per cent. removed by decantation.
d. Department of Highways uses round openings for 3/8 inch and over.

gheny River (Washington Crossing), and the Becks Run bridge of the Pennsylvania Railroad.

Table II is a comparative statement of the requirements for the grading of coarse aggregates under the specifications of the Joint Committee, the Department of Highways of Pennsylvania, and those proposed by the Committee of the Engineers' Society of Western Pennsylvania.

Table III is a partial record of sieve analyses of sand used in the Washington Crossing bridge, and shows the fineness modulus for each sample. It also shows the grading of a sand from Warren, Pa., and one proposed by the Robert W. Hunt Company as an "ideal sand."

Table IV shows minimum, maximum, and average values for grading of sand used in the Becks Run bridge of the Pennsylvania Railroad. Fineness moduli are also shown.

TABLE II. SPECIFICATION REQUIREMENTS FOR COARSE AGGREGATES

Maximum percentage to be retained on Tyler standard sieves

	Size	3″	2″	1½″	1¼″	1″	¾″	⅝″	½″	⅜″	No. 4	No. 8
Joint Committee	3″	a5	...	25–60	.....	.....	.....	......	..	......	b90	b95
	2″	....	a5	.....	.....	25–60	.....	......	..	......	b90	b95
	1½″	....	...	a5	.....	.....	25–60	......	..	......	b90	b95
	1″	....	...	.....	.....	a5	.....	......	..	......	b90	b95
	¾″	....	...	....	....	.....	a5	......	..	......	b90	b95
	½″	....	...	.....	.....	.....	.....	......	a5	......	b90	b95
Department of Highways of Pennsylvania												
Class A		....	...	.....	.....	.....	.....	......	..			
Concrete		....	...	.....	0	.....	.....	......	..	b92	...	..
Class B-Cc		(2¾″) 0	0–5	.....	35–70	.....	.....	85–100	..	92–100	...	...
Slag		(2½″) 0	0–5	.....	25–75	.....	.....	85–100	..	85–100	...	..
Engineers' Society of Western Pennsylvania												
Small		....	...	.....	.....	.....	a5	......	..	30–70	b98	...
Medium		....	...	a0	.....	.....	30–60	......	..	b85	...	...
Large		(2¾″) 0	...	15–40	.....	....	25–75	......	..	b85	b90	b95

a. Not more than.
b. Not less than.
c. For ⅜-inch openings, and larger, the Department of Highways of Pennsylvania uses round openings.

TABLE III. SIEVE ANALYSES OF SAND
Percentage retained on Tyler standard sieves

	3/8	No. 4	No. 8	No. 14	No. 28	No. 48	No. 100	Fineness modulus
			Washington Crossing bridge					
....	....	1.0	27.0	39.5	65.6	92.1	98.3	3.24
....	....	2.0	12.0	26.5	49.5	90.0	98.0	2.78
....	....	0.5	12.5	23.5	83.5	85.0	96.0	3.01
....	....	1.0	10.5	21.0	38.0	75.0	94.0	2.40
....	....	1.5	19.0	26.5	35.0	80.5	95.0	2.67
....	....	0.5	17.0	35.0	53.5	90.0	98.0	2.94
....	....	0.5	16.5	30.0	55.5	89.0	98.0	2.90
....	....	1.0	8.5	15.0	25.5	75.0	96.5	2.22
....	....	0.5	26.5	41.5	50.5	73.5	95.0	2.87
....	....	0.5	18.5	31.5	46.0	88.0	98.0	2.82
....	....	1.0	17.5	38.0	60.0	90.0	98.0	3.04
....	....	12.5	28.8	33.8	41.8	88.0	98.0	3.03
....	....	14.5	37.0	46.0	56.0	87.0	97.0	3.38
....	....	7.5	28.5	42.0	55.2	90.0	99.0	3.22
....	....	11.0	35.0	50.0	65.8	91.0	98.0	3.51
....	....	0.5	13.5	26.5	48.0	88.0	99.0	2.76
....	....	1.0	15.0	26.5	40.5	86.0	97.0	2.66
....	....	8.0	25.0	33.0	43.0	70.0	94.0	2.73
....	....	0.5	6.0	15.0	30.0	83.0	98.0	2.32
....	....	0.5	12.0	25.0	43.0	87.0	96.0	2.64
....	....	0.6	12.6	25.8	43.6	87.4	97.4	2.67
....	....	0.8	12.8	24.2	40.2	83.2	96.8	2.58
....	....	11.6	29.2	36.4	45.6	77.0	95.0	2.95
....	....	13.6	32.3	40.9	50.3	83.9	97.2	3.18
....	....	5.1	22.8	30.0	34.0	74.6	97.4	2.64
....	....	1.0	18.2	34.1	55.4	85.1	96.8	2.91
....	....	5.4	22.2	31.4	48.0	83.6	97.2	2.88
....	....	0.0	10.0	25.4	57.2	91.8	99.6	2.84
....	....	0.0	8.4	20.6	68.6	90.4	97.8	2.86
Minimum.....	....	0.0	6.0	15.0	25.5	73.5	94.0	2.22
Maximum.....	....	14.5	37.0	50.0	83.5	92.1	99.6	3.51
Average.......	....	3.6	19.13	30.85	49.27	84.66	97.10	2.85
			Warren, Pa.					
....	....	13.0	32.8	50.4	68.7	88.8	96.1	3.50
			Robert W. Hunt Company					
....	....	0.0	41.0	64.0	77.5	90.0	100.0	3.72

TABLE IV. SIEVE ANALYSES OF SAND

Percentage retained on Tyler standard sieves

	3/8	No. 4	No. 8	No. 14	No. 28	No. 48	No. 100	Fineness modulus
Becks Run								
7 cars 0–No. 14								
Minimum	0.0	0.0	4.0	10.0	21.0	78.0	98.0	2.17
Maximum	1.0	1.0	7.0	14.0	32.0	97.0	99.0	2.42
Average	0.1	0.4	6.4	12.3	25.3	89.1	98.9	2.33
39 cars 0–No. 8								
Minimum	0.0	0.0	6.0	14.0	22.0	74.0	97.0	2.23
Maximum	0.0	2.0	14.0	28.0	50.0	98.0	100.0	2.85
Average	0.0	0.4	9.5	19.0	36.1	88.5	98.8	2.53
13 cars 0–No. 4								
Minimum	0.0	0.0	15.0	23.0	36.0	86.0	98.0	2.67
Maximum	...	....	34.0[a]	49.0[a]	64.0[a]	....	....	3.38[a]
Maximum	0.0	12.0	26.0	39.0	59.0	97.0	100.0	3.23
Average	0.0	2.5	19.5	30.8	48.5	92.0	99.0	2.92
10 cars 0–3/8								
Minimum	0.0	2.0[a]	....	....	....	....	....	....
Minimum	...	15.0	27.0	33.0	42.0	86.0	97.0	3.09
Maximum	...	....	47.0[a]	63.0[a]	75.0[a]	92.0[a]	....	3.77[a]
Maximum	8.0	25.0	44.0	51.0	61.0	92.0	99.0	3.69
Average	1.0	17.2	36.1	44.6	54.8	89.5	98.3	3.42

Percentage retained on 3/4-inch screen Minimum 0.0
Maximum 3.0
Average 0.3

a. Crushed sand.

TABLE V. SIEVE ANALYSES OF GRAVEL

Percentage retained on Tyler standard sieves

	1½″	¾″	⅜″	No. 4	No. 8	No. 14	No. 28	No. 48	No. 100	Fineness modulus
	Piers		Washington Crossing bridge							
....	13.7	22.4	60.1	89.0	98.2	99.6	100.0	100.0	100.0	6.92
....	0.0	28.8	47.5	60.0	68.8	70.6	78.1	99.1	100.0	5.53
....	7.7	71.0	91.0	100.0	100.0	100.0	100.0	100.0	100.0	7.69
....	0.0	39.3	78.6	96.5	98.3	98.7	98.9	99.5	100.0	7.09
....	0.0	15.0	47.0	90.0	100.0	100.0	100.0	100.0	100.0	6.52
....	19.2	30.0	53.7	75.0	97.0	100.0	100.0	100.0	100.0	6.75
....	0.0	34.6	95.3	100.0	100.0	100.0	100.0	100.0	100.0	7.30
....	0.0	19.0	75.4	97.8	100.0	100.0	100.0	100.0	100.0	6.92
....	0.0	50.4	71.8	91.4	100.0	100.0	100.0	100.0	100.0	7.14
....										
Minimum........	0.0	15.0	47.0	60.0	68.8	70.6	78.1	99.1	100.0	5.53
Maximum........	19.2	71.0	95.3	100.0	100.0	100.0	100.0	100.0	100.0	7.69
Average.........	4.51	34.50	68.93	88.86	95.81	96.54	97.44	99.84	100.0	6.87
Piles............	....	1.0	33.0	82.7	93.7	95.2	100.0	100.0	100.0	6.05
....	....	2.0	36.0	87.5	98.0	99.5	100.0	100.0	100.0	6.23
....										
Average.........	....	1.50	34.5	85.1	95.6	97.4	100.0	100.0	100.0	6.14

TABLE VI. SIEVE ANALYSES OF GRAVEL
Becks Run bridge
Percentage retained on Tyler standard sieves

		1½″	¾″	⅜″	No. 4	No. 8	No. 14	No. 28	No. 48	No. 100	Fineness modulus
7 cars 1″ Commercial	Minimum..	....	0.0	29.0	76.0	94.0	97.0	97.0	98.0	99.0	5.94
	Maximum..	....	1.0	64.0	84.0	99.0	100.0	100.0	100.0	100.0	6.41
¾″—No. 8	Average....	....	0.1	39.8	79.9	96.9	98.4	99.0	99.5	99.6	6.13
16 cars 1″ Commercial	Minimum..	....	0.0	39.0	86.0	97.0	98.0	98.0	98.0	99.0	6.215
¾″—No. 4	Maximum..	....	14.0	72.0	97.0	100.0	100.0	100.0	100.0	100.0	6.75
	Average....	....	2.8	51.6	91.3	98.4	99.0	99.2	99.3	99.5	6.41
17 cars 1½″ Commercial	Minimum..	0.0	15.5	53.5	86.0	96.5	97.0	98.0	98.5	99.0	6.53
1″—No. 4	Maximum..	6.5	29.0	72.5	97.0	100.0	100.0	100.0	100.0	100.0	6.925
	Average....	0.7	22.3	64.6	91.2	98.0	98.6	98.9	99.2	99.7	6.72
10 cars 1½″ Commercial	Minimum..	0.0	32.0	85.0	96.0	97.0	97.5	98.0	98.5	99.0	7.185
1″—⅜	Maximum..	3.0	51.0	97.0	99.0	99.5	100.0	100.0	100.0	100.0	7.415
	Average....	0.3	41.8	91.8	97.7	98.6	99.0	99.7	99.9	99.9	7.29
2 cars 1½″ Commercial	Minimum..	0.0	25.5	52.0	84.0	96.0	98.5	99.5	100.0	100.0	6.555
1½″—No. 4	Maximum..	0.0	31.5	69.0	94.0	99.0	99.0	99.5	100.0	100.0	6.92
	Average....	0.0	28.5	60.5	89.0	97.5	98.7	99.5	100.0	100.0	6.74
36 cars 1½″—⅝	Minimum..	0.0	45.0	87.5	97.5	98.0	99.0	99.5	100.0	100.0	7.395
Commercial	Maximum..	5.5	69.0	99.5	100.0	100.0	100.0	100.0	100.0	100.0	7.69
1½″—⅜	Average....	0.8	59.2	96.9	98.9	99.5	99.9	100.0	100.0	100.0	7.55
9 cars 2½″—⅝	Minimum..	17.0	62.0	89.0	94.5	96.5	97.0	97.5	98.5	99.5	7.73
Commercial	Maximum..	35.5	72.5	97.3	99.5	99.6	99.8	100.0	100.0	100.0	7.97
2″—⅜	Average....	26.0	68.9	93.7	97.9	98.9	99.1	99.2	99.6	99.7	7.83

Table V shows a partial record of the sieve analyses made on gravel for Bridge Number Seven, Allegheny River (Washington Crossing) ; first for piers and, second, for pre-cast piles.

Table VI shows minimum, maximum, and average values for the sieve analyses made on gravel for the Becks Run bridge of the Pennsylvania Railroad.

The curves in Fig. 1 show minimum, maximum, and average values of sieve analyses of sand and 1½-inch gravel used in the Washington Crossing bridge.

The heavy vertical lines show the limits fixed by the specifications proposed by your Committee, and the double lines show the limits fixed by the Joint Committee.

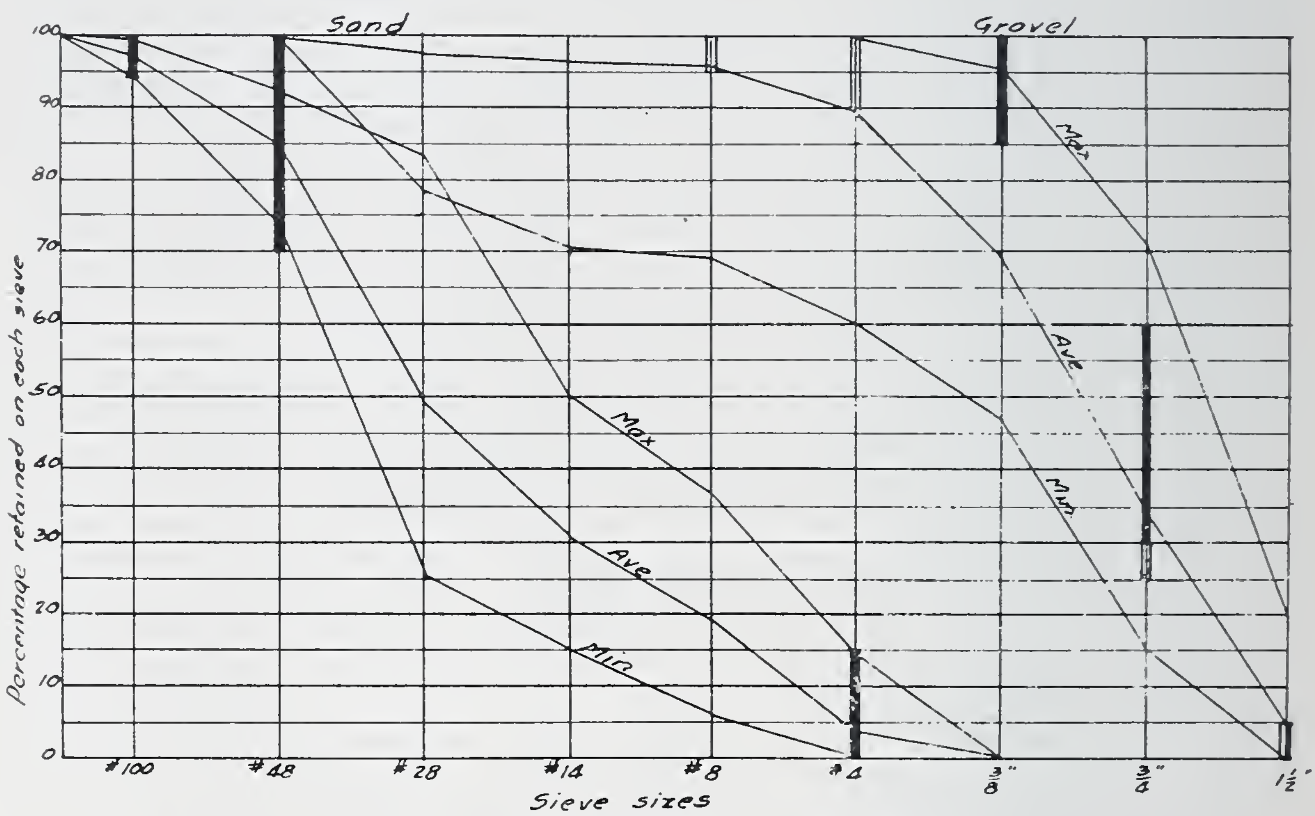

Fig. 1. Sieve Analyses of Sand and Gravel Used in Washington Crossing Bridge.

It will be seen that the gravel contained more fine material than permitted by the proposed specifications, though it fairly well met the specifications of the Joint Committee, while the sand met the requirements of both.

Fig. 2 relates to the Becks Run bridge. As in the case of the Washington Crossing bridge, it will be seen that the gravel contained an excess of fine material, while the sand quite generally complied with the requirements of the specifications of the Joint Committee and of those proposed.

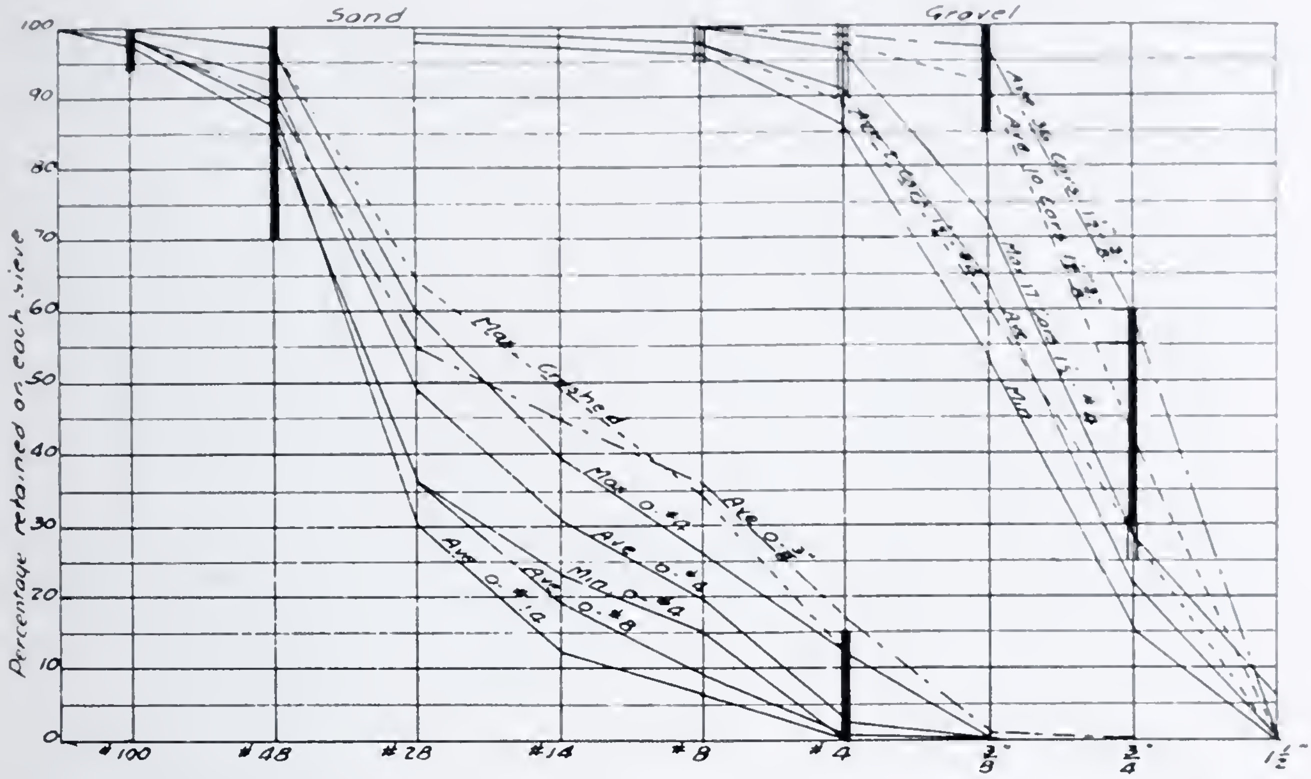

Fig. 2. Sieve Analyses of Sand and Gravel Used in Becks Run Bridge.

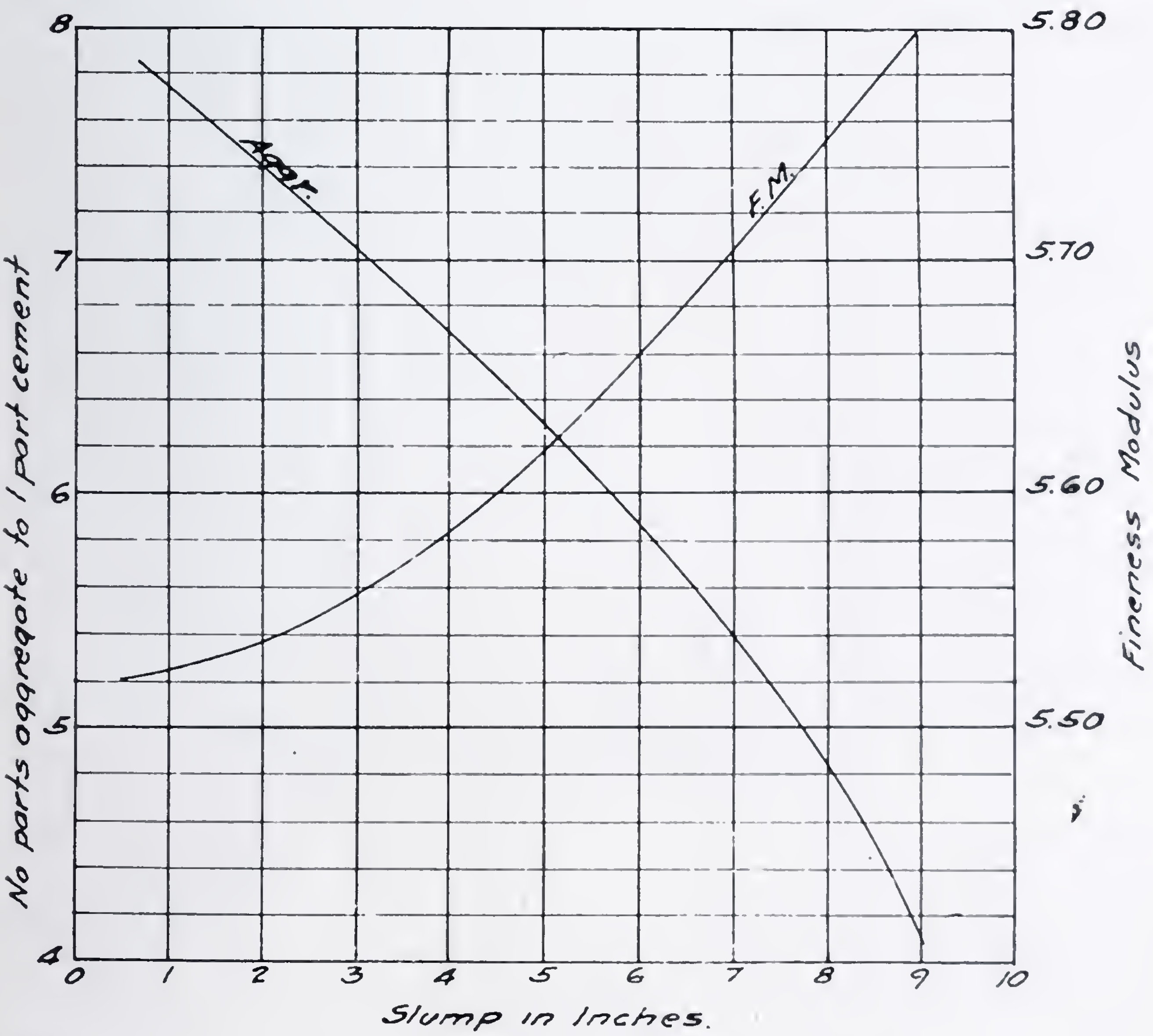

Fig. 3. Data for 1500-Pound Concrete.

Fig. 3-6 show fineness moduli and ratio of aggregates to cement for varying amounts of slump. The size of aggregate is up to 1½ inch.

These charts were developed from others published by the Portland Cement Association, and drawn to a small scale. Curves pre-

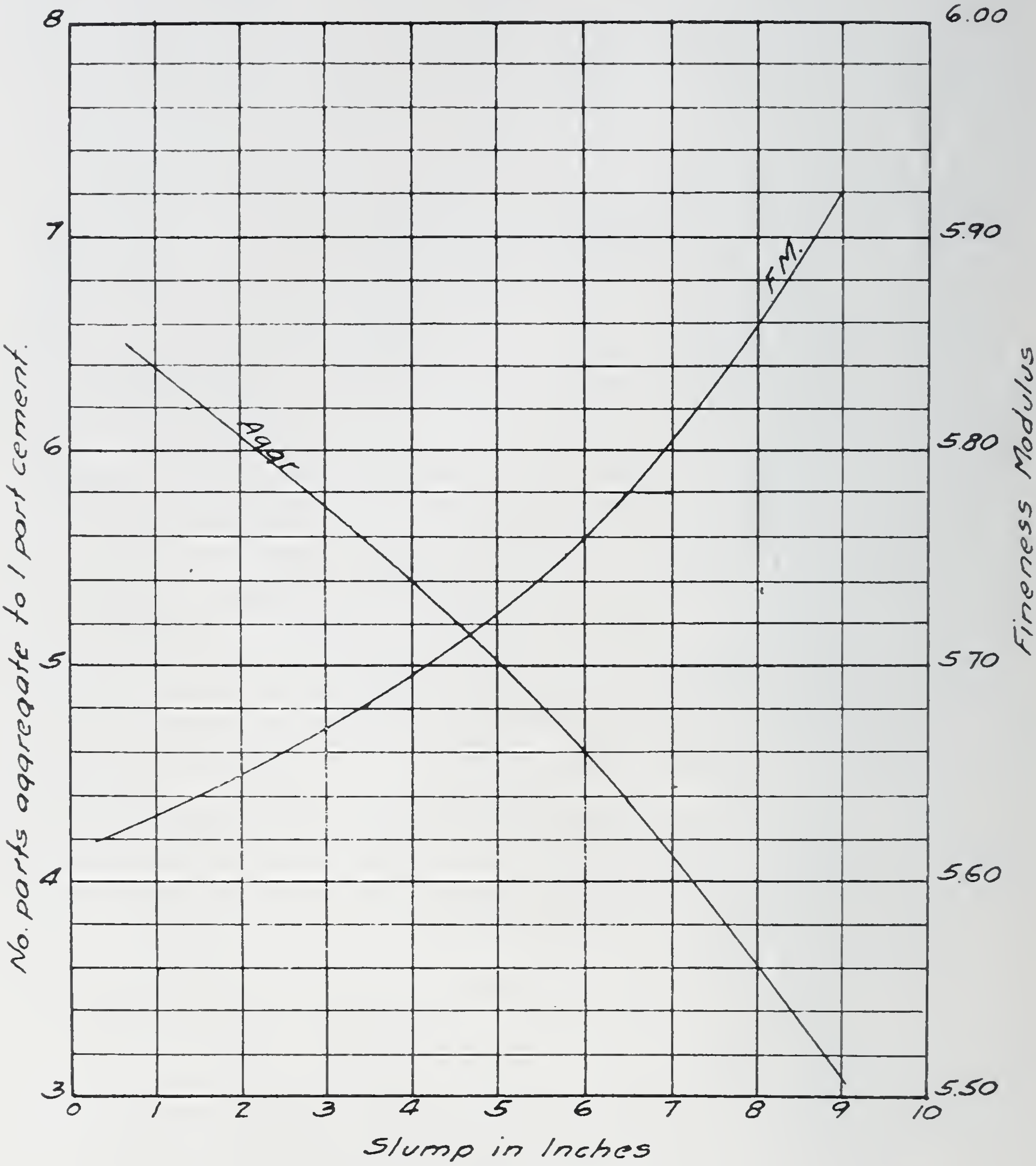

Fig. 4. Data for 2000-Pound Concrete.

pared under such conditions lack that degree of accuracy obtained when plotted from the original data.

Fig. 7, made by Mr. Arthur A. Levison, shows the increase in volume of sand due to moisture, and demonstrates clearly that it is

necessary to determine the amount of moisture carried in the sand. This is for two reasons:

1. In order to determine the amount of water to add.

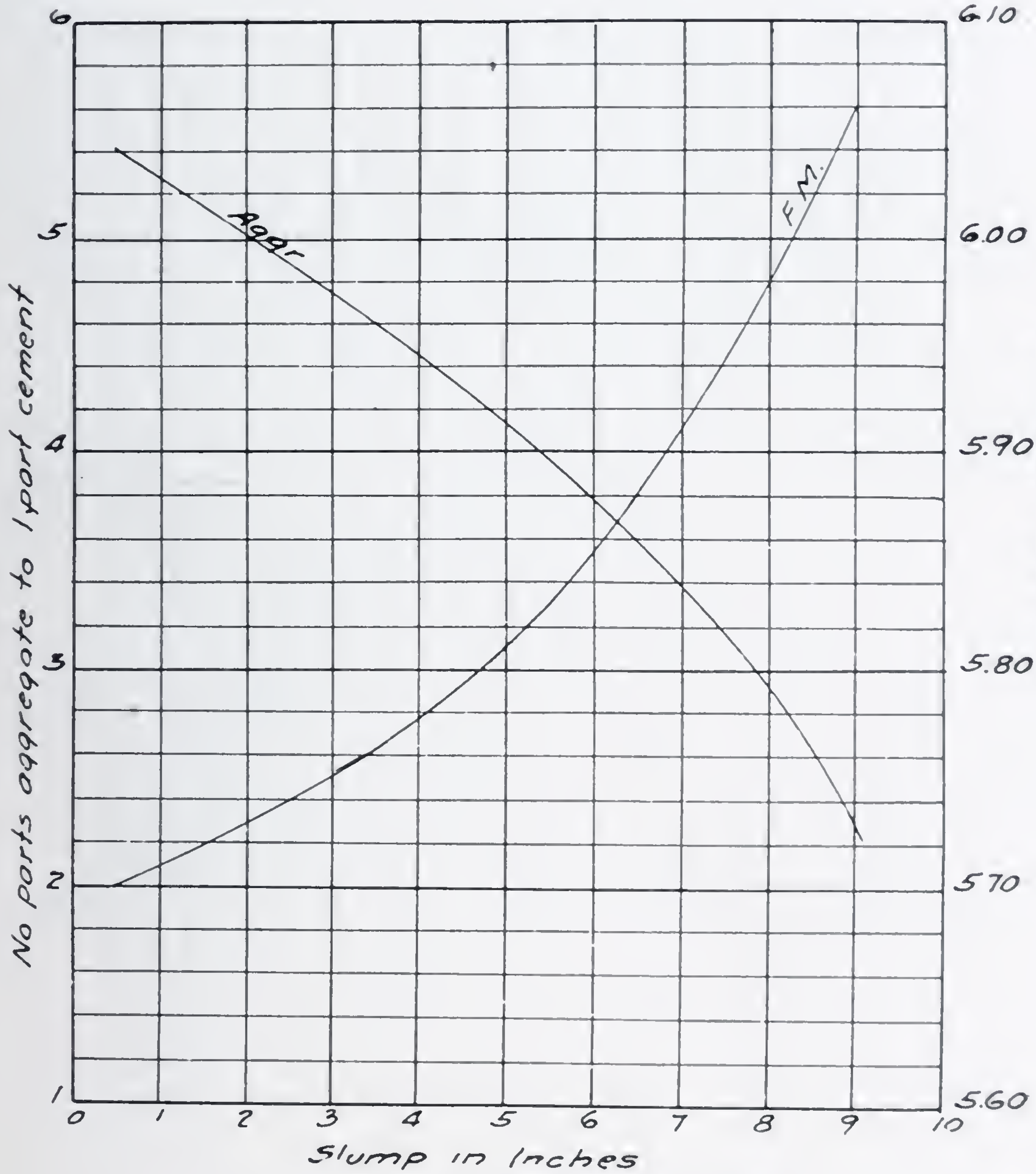

Fig. 5. Data for 2500-Pound Concrete.

2. To determine the correct volume of sand to use in making concrete.

With moisture between zero and three per cent., the volume of sand increases rapidly. Above five per cent., the bulking falls off as moisture increases until a state of saturation is reached.

Fig. 8 gives the amount of water contained, and the weight of dry sand contained, in one cubic foot of moist sand. The values are calculated from the bulking curve by Mr. Levison.

Fig. 9 enables one to determine the ratio of fine to coarse aggre-

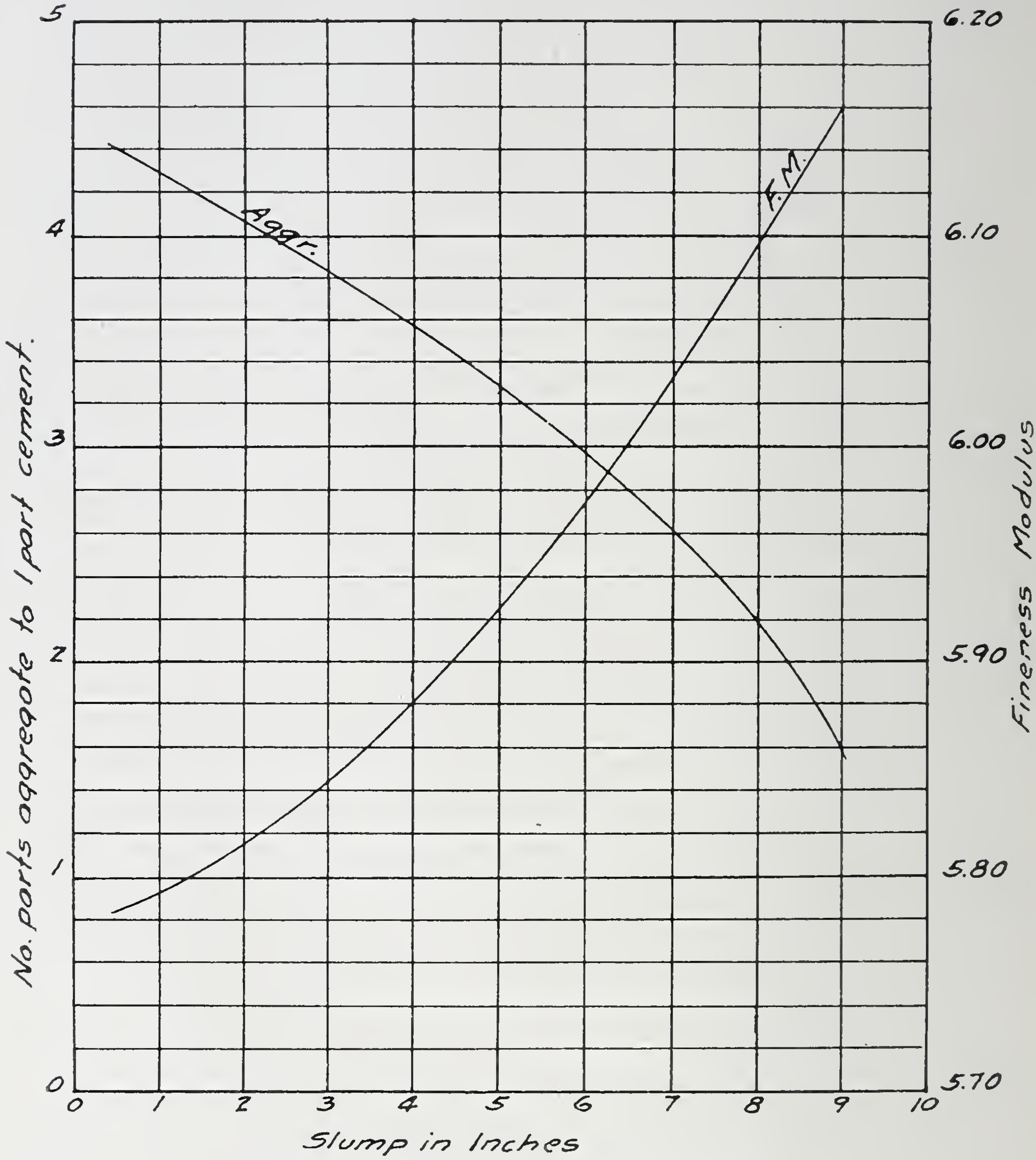

Fig. 6. Data for 3000-Pound Concrete.

gate to produce a combined aggregate of a desired fineness modulus. For example, assume a coarse aggregate with a fineness modulus of 7, a fine with a fineness modulus of 3, and a desired fineness modulus of 5.

$$Mc - M = 2 \text{ and } Mc - Mf = 4.$$

TABLE VII. CHART FOR DESIGNING CONCRETE MIX

Grade of concrete	2000-pound
Ratio of water to cement	0.90
Gallons of water per sack	6.75
Slump desired	5-inch
FM = Fineness modulus desired	5.72
Ratio of aggregates to cement measured mixed	5
Maximum size of aggregates	1½-inch

FM_C = Fineness modulus of coarse aggregate	FM_F = Fineness modulus of fine aggregate	Percentage of aggregates: Fine	Percentage of aggregates: Coarse	No. of parts of aggregates to 1 part cement: Fine	No. of parts of aggregates to 1 part cement: Coarse	Ratio of mixed aggregates ÷ sum of fine and coarse, measured separately	No. of parts aggregates measured separately: Fine	No. of parts aggregates measured separately: Coarse	Condition of aggregate when used	Amount of water per cent by weight: Fine	Amount of water per cent by weight: Coarse	Allowance for bulking of aggregates, per cent: Fine	Allowance for bulking of aggregates, per cent: Coarse	No. of parts aggregates corrected for bulking: Fine	No. of parts aggregates corrected for bulking: Coarse	Final ratio: Cement	Final ratio: Fine aggregate	Final ratio: Coarse aggregate	Water content of aggregates in gallons: Fine	Water content of aggregates in gallons: Coarse	Water content of aggregates in gallons: Total	Allowance for absorption in gallons	Gallons of water to be added per sack of cement
Maximum 7.70	Maximum 3.50	0.47	0.53	2.35	2.65		2.74	3.05	Dry	0	0	0	0	2.74	3.05	1	2.74	3.08	0	0	0	0.74	7.50
									Moist	4	½	28	0	3.51	3.08	1	3.51	3.08	1.97	0.20	2.17	0.74	5.33
									Wet	15	1½	20	0	3.29	3.08	1	3.29	3.08	4.07	0.01	5.71	0.74	1.79
	Average 2.80	0.40	0.60	2.00	3.00		2.33	3.49	Dry	0	0	0	0	2.33	3.49	1	2.33	3.49	0	0	0	0.74	7.50
									Moist	5	½	28	0	2.98	3.49	1	2.98	3.49	1.07	0.23	1.90	0.74	5.60
									Wet	15	1½	20	0	2.80	3.49	1	2.80	3.49	4.23	0.70	4.93	0.74	2.57
	Minimum 2.20	0.36	0.64	1.80	3.20		2.10	3.72	Dry	0	0	0	0	2.10	3.72	1	2.10	3.72	0	0	0	0.74	7.50
									Moist	6	½	28	0	2.60	3.72	1	2.09	3.72	1.51	0.25	1.70	0.74	5.74
									Wet	15	1½	20	0	2.52	3.72	1	2.52	3.72	3.81	0.74	4.55	0.74	2.95
Average 6.70	Maximum 3.50	0.31	0.69	1.55	3.45		1.80	4.02	Dry	0	0	0	0	1.80	4.02	1	1.80	4.02	0	0	0	0.75	7.50
									Moist	8	½	28	0	2.30	4.02	1	2.30	4.02	1.29	0.27	1.56	0.75	5.94
									Wet	15	1½	20	0	2.16	4.02	1	2.10	4.02	1.26	0.80	4.06	0.75	3.44
	Average 2.80	0.25	0.75	1.25	3.75	0.86	1.45	4.36	Dry	0	0	0	0	1.45	4.36	1	1.45	4.36	0	0	0	0.75	7.50
									Moist	6	½	28	0	1.86	4.36	1	1.86	4.36	1.04	0.29	1.33	0.75	6.17
									Wet	15	1½	20	0	1.71	4.36	1	1.74	4.36	2.63	0.87	3.50	0.75	4.00
	Minimum 2.20	0.22	0.78	1.10	3.90		1.28	4.54	Dry	0	0	0	0	1.28	4.54	1	1.28	4.54	0	0	0	0.75	7.50
									Moist	5	½	28	0	1.61	4.54	1	1.64	4.54	1.03	0.30	1.33	0.75	6.17
									Wet	15	1½	20	0	1.53	4.54	1	1.53	4.54	2.31	0.91	3.22	0.75	4.38
Minimum 6.50	Maximum 3.50	0.26	0.74	1.30	3.70		1.51	4.31	Dry	0	0	0	0	1.51	4.31	1	1.51	4.31	0	0	0	0.75	7.50
									Moist	6	½	28	0	1.93	4.31	1	1.93	4.31	1.08	0.29	1.37	0.75	6.13
									Wet	15	1½	20	0	1.81	4.31	1	1.81	4.31	2.71	0.80	3.60	0.75	3.90
	Average 2.80	0.21	0.79	1.05	3.95		1.22	4.60	Dry	0	0	0	0	1.22	4.60	1	1.22	4.60	0	0	0	0.76	7.50
									Moist	5	½	28	0	1.56	4.60	1	1.56	4.60	0.87	0.31	1.18	0.76	6.32
									Wet	5	1½	20	0	1.46	4.60	1	1.46	4.60	2.21	0.92	3.13	0.76	4.37
	Minimum 2.20	0.18	0.82	0.90	4.10		1.05	4.77	Dry	0	0	0	0	1.05	4.77	1	1.05	4.77	0	0	0	0.70	7.50
									Moist	4	½	28	0	1.34	4.77	1	1.34	4.77	0.75	0.32	1.07	0.70	6.43
									Wet	15	1½	20	0	1.26	4.77	1	1.26	4.77	1.90	0.95	2.65	0.70	4.65

Follow the vertical through $Mc - Mf = 4$ to its intersection with the curve $Mc - M = 2$. This is on the horizontal r = 50, and hence 50 per cent. of total aggregates shall be sand.

Table VII has been prepared to show the procedure to be followed in the design of concrete mix and to illustrate the great number of possible combinations of materials resulting from the variation in qualities and conditions of the various materials used. With only three grades each of coarse and fine aggregates, and with only three

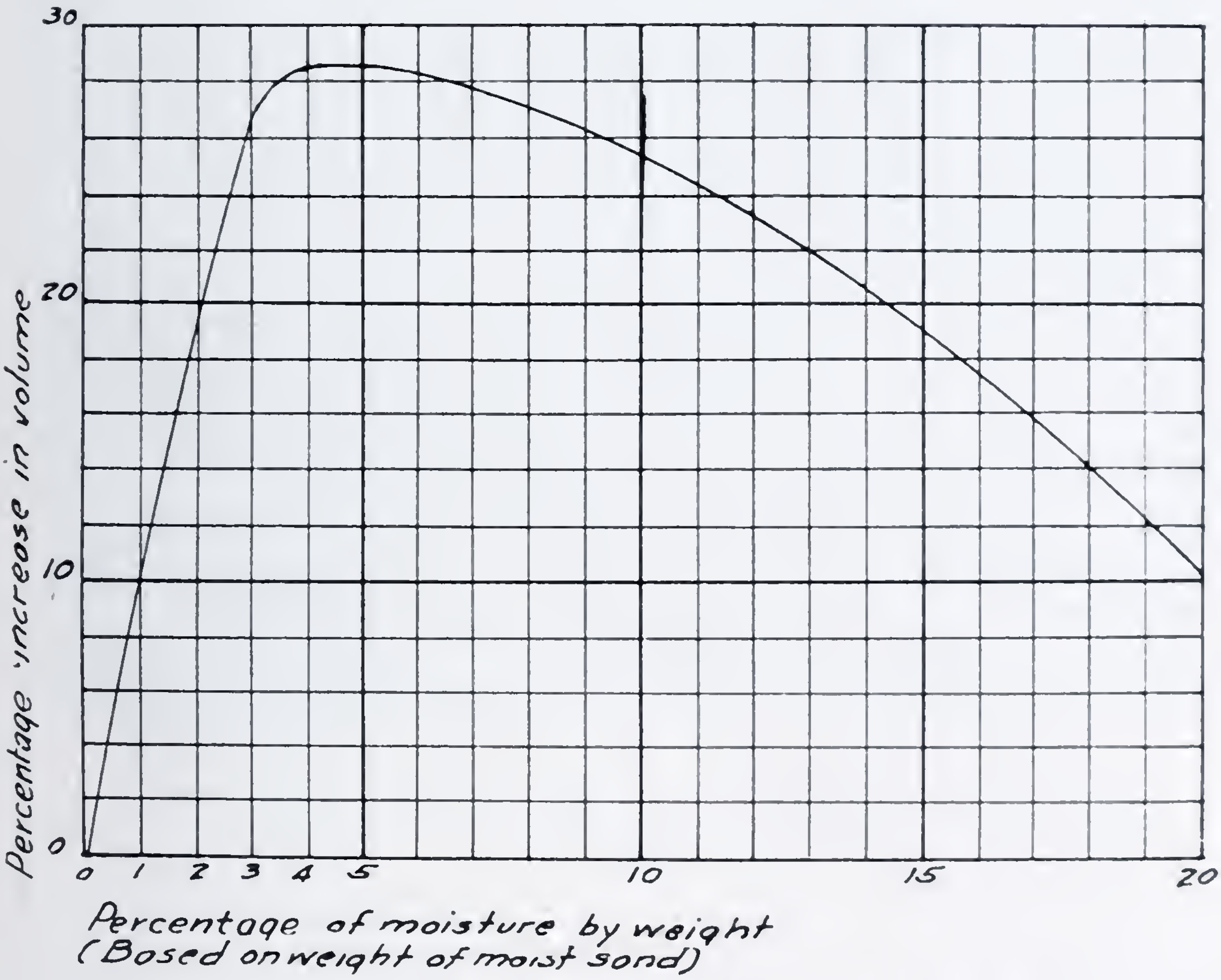

Fig. 7. Curve Showing Bulking of Allegheny River Sand.

conditions of moisture in the sand, there are 27 combinations, only one of which, in any particular case, will produce the desired grade of concrete. It is, therefore, evident that in order to secure concrete of the desired grade it will be necessary to guard each step carefully.

In designing a concrete mix, the first thing to determine is the quality desired (the chart is worked out for concrete having a crushing strength of 2000 pounds per square inch). Having fixed upon the grade of concrete desired, the ratio of water to cement is at once

definitely fixed. The next thing to determine is the workability of the mix. The amount of slump is a measure of workability. Having fixed the slump to give the workability desired, the fineness modulus of the combined aggregates and the ratio of aggregates to cement,

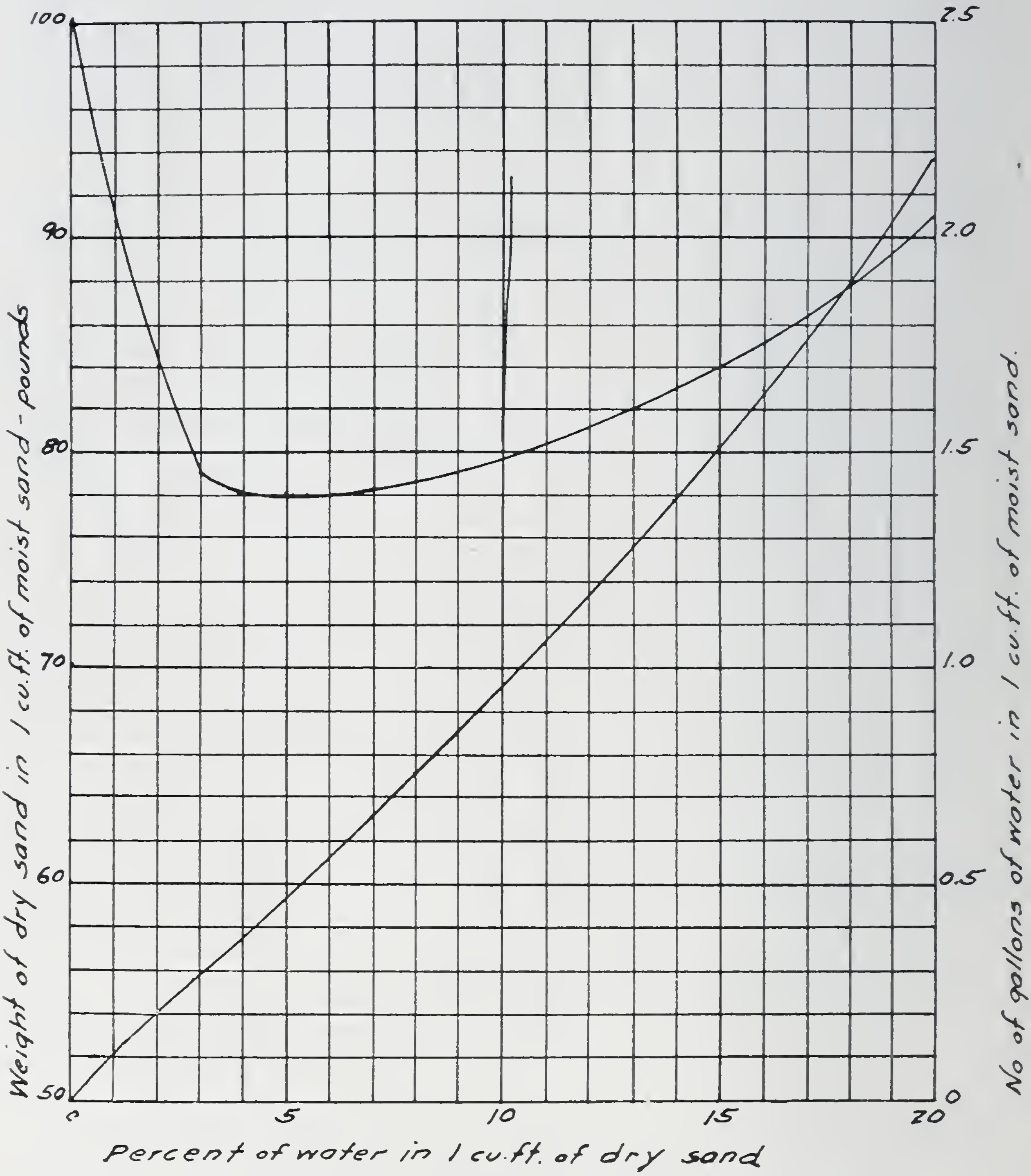

Fig. 8. Water and Sand in a Cubic Foot of Moist Sand.

follow. It is then necessary to determine the fineness modulus of each (coarse and fine) aggregate in order to fix upon the ratio of fine to coarse that will give the desired fineness modulus of the combined mix.

In computing the amount of each of the aggregates it is necessary to make a correction on account of shrinkage in volume when the two are mixed. Ordinarily, the volume after being mixed is 86 per cent. of the sum of the volumes measured separately. Before measuring the fine aggregate, it is necessary to make another correction due to the bulking on account of the contained moisture. After

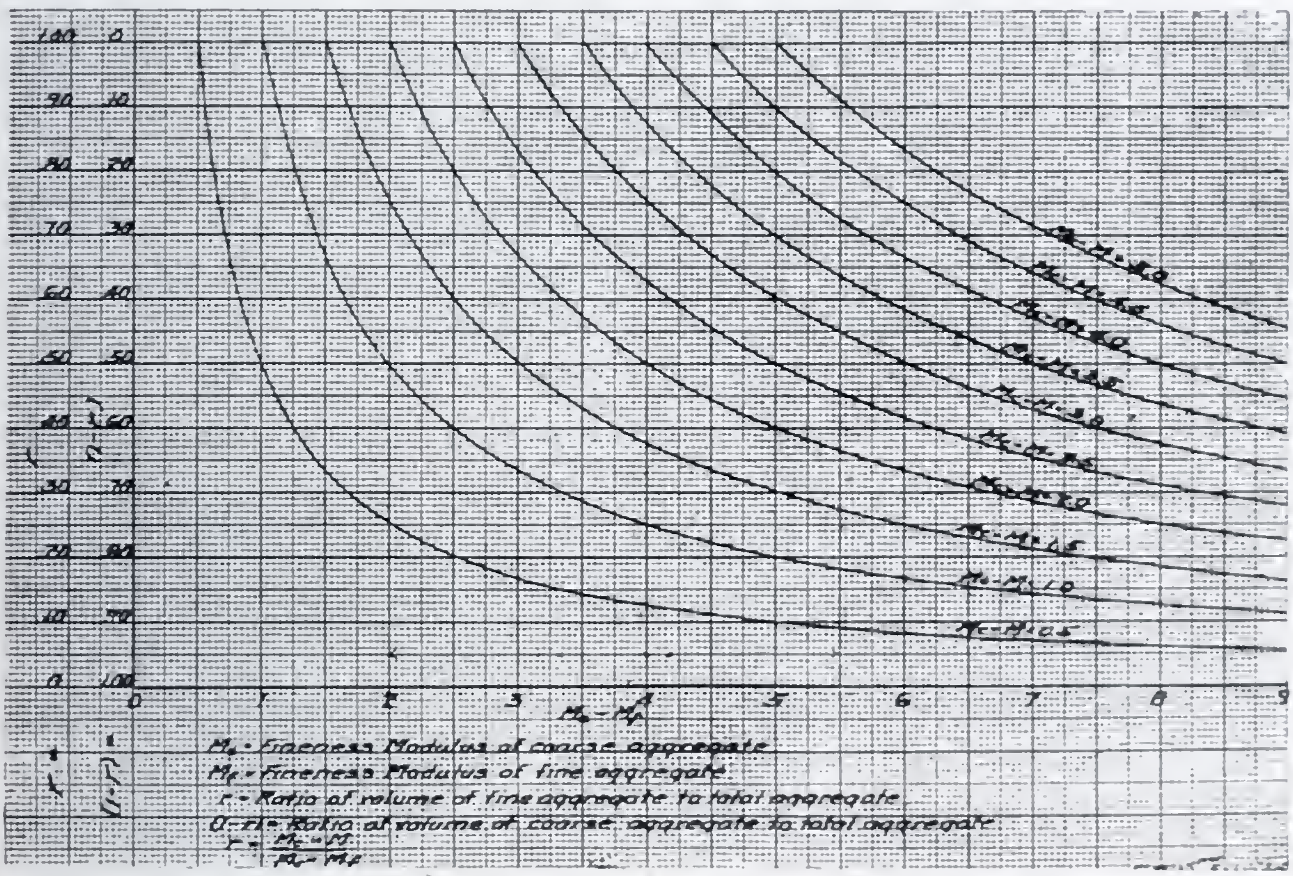

Fig. 9. Determination of Fineness Modulus for Mixed Fine and Coarse Aggregate.

having made these corrections the aggregates can be properly proportioned. Before adding water to the mix, it is necessary to determine the amount of water carried in the aggregates and deduct this amount from the total amount of water required. If this is not done, there will be an excess of water in the mix, and consequently a reduction in the strength of the concrete.

DISCUSSION

C. S. Davis: In connection with the report, it may be well to explain or amplify certain statements. The following comments are numbered to correspond with the numbered paragraphs of the report.

FINE AGGREGATE

1. You will notice that crushed sandstone, crushed limestone, and slag are omitted. It is the belief of the Committee that these would not make good materials for fine aggregate.

2. The percentage of coal permissible in the fine aggregate is double that in the coarse aggregate. That is due to the fact that the finer particles carried in the sand are not as injurious in concrete as the larger particles carried in the coarse material.

3. The Committee recognizes the merit of the colorimetric test, but at the same time realizes that a small amount of lignite, which would not necessarily be injurious to the concrete, will show color in the test to an extent that would cause rejection if that test were made of a positive designation, and the prevalence of lignite in this district is such as to make that inadvisable, in the opinion of the Committee.

5. There is not a very great deal of difference between the two grades of sand other than that the coarser particles have been removed from the coarse to give the fine and to make a sand suitable for plaster. Those who desire a finer sand in a mix for concrete can make use of this sand in place of the coarser in specifying. The requirements are pretty fairly within what is found in common practice in this district at the present time, and we do not feel that there is any great burden put upon the producers to furnish fine aggregate of these two grades.

COARSE AGGREGATE

10. In reference to sieve sizes, these specifications are for laboratory tests, or for field tests, and do not necessarily mean that the producer shall use screens or sieves of the sizes or openings noted herein. The object is that the product he delivers shall meet the test stated herein. You will notice that the soundness test applies to slag and crushed stone, but does not apply to gravel. It was left in that way because, at the present time, the Committee has no satisfactory test for the soundness of gravel.

The same reasoning applies to the last paragraph. The Committee has no satisfactory test to apply for those qualities of gravel and slag.

In getting the coarse aggregate, these specifications will make it necessary to remove more of the finer particles than is, perhaps, common practice.

V. R. COVELL:* Concrete which is made up very largely of these aggregates is used extensively throughout the Pittsburgh district, and we are all aware of the fact that there is both good and bad concrete. If the engineer has any one function above another in this matter, it is to determine the qualities of aggregates necessary to produce good concrete at a reasonable cost. I believe that it was with this purpose in mind that this Committee was appointed, and it is toward this object that the members have been working so faithfully through these months in preparing this report. In order that the report may have the fullest value to the Society and to the members of the engineering profession in general, we need to have the expression of everyone here who has had experience along these lines as to whether the best standards which can be worked out under existing conditions have been reached. We shall be glad to hear from anyone who desires to ask questions or who can contribute in any way to the discussion.

P. J. FREEMAN:† You want to bear in mind that these specifications are intended only to take care of general conditions, with the idea of limiting the number of sizes of material demanded of the producers in this district. We considered the use of screenings in concrete and, so far as we know at the present time, we would not be in favor of recommending screenings the way they are usually prepared. The Committee would not say that they could not be used or are not permissible, but, for the present, the things we are recommending are perfectly safe to use and may be applied all the way through. There may be other sizes of aggregates which you may need for your various purposes, such as concrete block. We have not attempted to take care of that; we are only aiming at a standardization.

*Chief Engineer, Bureau of Bridges, Department of Public Works, Allegheny County, Pittsburgh.

†Chief Engineer, Tests and Specifications, Allegheny County, Pittsburgh.

V. R. Covell: I wonder if a little more emphasis should not be placed upon that—the importance of a specification which will meet conditions, and at the same time call for aggregates that can be readily produced without excessive cost. Isn't that really what you are after?

P. J. Freeman: That is what we tried to do. We went over the records of many tests that have been made on various jobs and we endeavored to fix a reasonable specification which can be met at the present time; for instance, this question of one per cent. by weight of coal. Certainly we should not permit any more than one per cent., for, in a 500-ton barge, that will give you five tons of coal, which is quite a lot. We went over the records of perhaps a thousand tests where we knew the amount of coal had been determined, and, although a few ran as high as 2½ per cent., we feel that present practice can easily be held down to one per cent. Maybe a year from now we can cut it down to ½ per cent., but the Committee did not feel that it was fair to the producers to demand ½ per cent. at the present time.

C. D. Foight:* I should like to ask whether the Committee considered the matter of the uniformity coefficient of the various sizes of aggregates?

P. J. Freeman: Just where does the gentleman mean to apply the uniformity coefficient—for filtration work or for concrete?

C. D. Foight: Concrete.

P. J. Freeman: The Committee did not consider the uniformity coefficient. These specifications are intended to cover average practice and average conditions which can be obtained in this district. It did not seem to the Committee that it was advisable at this time to enter into any theoretical considerations other than the ability to obtain the product which will give concrete of reasonable quality.

E. V. Braden:† We should like to follow these specifications in selecting material for our various jobs and I should like to hear

*Draftsman and Designer, Rust Engineering Co., Pittsburgh.
†Chief Engineer, Pittsburgh, Chartiers & Youghiogheny Railway Co., Pittsburgh.

from some of the producers as to what they think would be the result if we all followed these specifications and just asked for these materials—whether we would get what we want and when we want it.

V. R. Covell: Let us be just a little informal and get at the facts. There is no motion on any of these items at the present time, yet we would be glad to hear from any of the producers as to whether it is possible to furnish economically any or all of the materials which are here described.

A. W. Dann:* I see no reason at all why these different sizes of sand and gravel can not be furnished by the producers. If that were not the case you would have heard from me a long time ago.

D. C. Elphinstone:† The specifications are very fair and we can meet them.

P. W. Price:‡ I should like to ask how much difference it would make if the one per cent. of coal were figured by volume instead of weight?

P. J. Freeman: About 2 or 2½ per cent. The Committee fixed it by weight so there would not be any room for argument. It is a very simple proposition to float the coal off with carbon tetrachlorid and weigh it directly and determine, without any room for argument, the actual percentage by weight.

P. W. Price: When you visualize the amount of coal by volume at 2½ per cent. it seems like a pretty liberal allowance of coal. Possibly that is higher than is necessary in ordinary practice and it might be lowered very easily.

F. M. McCullough:§ One reason for making the permissible limit of coal in gravel one-half that of sand was that, in the ordinary concrete mixes, the proportion of sand is about one-half that of gravel.

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†General Manager, Iron City Sand & Gravel Co., Pittsburgh.

‡Principal Assistant Engineer, Bureau of Bridges, Department of Public Works, Allegheny County, Pittsburgh.

§Professor of Civil Engineering, Carnegie Institute of Technology, Pittsburgh.

It follows then that one-half of one per cent. of coal in sand and one per cent. in gravel will result in the same amount of coal in the sand and in the gravel; and, therefore, the effect of these two percentages on the concrete will be the same.

P. J. FREEMAN: The Committee was not setting one per cent. for you to shoot at. We expected to keep it below ½ per cent., but it did not seem quite fair to introduce a new specification for coal (which exists to a large extent in this district) and make it too hard to start with. Not many people have data, but I think the average of the best producers at this time will run less than ½ per cent.

A. W. DANN: It is very much easier to remove the coal from the sand than from the gravel. That is because the particles of coal in the fine aggregate as it goes through the process of washing go out with the flow of water, but when you get pieces of coal an inch in diameter they are pretty hard to handle. When the coal commences to come pretty thick in the gravel we have to go somewhere else. From the standpoint of the producer, there were two things which were desirable in drawing up specifications for aggregates in the local market. The first consideration was that specifications should be drawn which would produce better concrete. We have all had at one time or another concrete which was just not so good, and the engineer and producer were in accord in wishing that situation to be remedied. I think the prime consideration in drawing these specifications is to make an aggregate which shall be better for that purpose. The producer is interested in it from that standpoint, as well as the engineer. He is also interested in it from the standpoint of economy of operation. The limiting of the number of sizes is important, both from the standpoint of quality and economy. It is important from the standpoint of economy, because the way things have been going for the past two or three years the tendency has been for various engineers to ask for material based on their own ideas as to specifications. During the course of a year there have been produced perhaps twenty different sizes of gravel in this district. That affects the quality, because the producer does not concentrate in making any one of those sizes as good as he might if they were more limited in number. It seems to us that these specifications are a step in bringing about that which we are trying to accomplish, which is better construction.

T. P. WATSON:* We regard the colorimetric test as a very practical field test and, without further test, condemn sand having a color as dark as the No. 3 shade suggested by the Portland Cement Association.

P. W. PRICE: In the first report there was a note that covered flat and soft pebbles. That was cut out. I suppose there was a good reason for it. I can not see why, if you say how much coal is allowable, you should not make a similar statement as to flat and soft gravel.

P. J. FREEMAN: That is one of the things on which the Committee did not have enough information. We say thin and flaky pieces, and again we sort of put it up to the engineer. Some specifications of various highway departments eliminate flats exceeding five per cent., and there again you have to specify what you mean by flats. Sometimes it means any pebble that has its greatest dimensions $2\frac{1}{2}$ times its least dimension; but it became too complicated for us and we did not put it in at this time. We do think that this may be taken care of later on.

T. P. WATSON: It has been my observation that the gravel produced in this district is made up of pebbles of varying sizes which, in general, have two nearly flat and parallel sides. The degree of flatness would be very difficult to define and it would be practically impossible to segregate any specified shape.

N. F. HOPKINS:† Doubtless the Committee has made tests on large test pieces. What were the results with the flat gravel?

P. J. FREEMAN: I do not believe you will find very much difference. There will not be any difference if the flats are placed properly in the specimen. Where you are making the ordinary 6- by 12-inch, or 8- by 16-inch specimens, if you tamp around and around and across the center and put the flats down, you will get the results of strength about the same as if they were not flat. If you tilt them up,

*Assistant Engineer, Pennsylvania Railroad Co., Pittsburgh.
†Civil and Mining Engineer, Harrop & Hopkins, Pittsburgh.

it will make quite a difference, as they shear off. The objection is not so much to the question of strength as to the question of size in highway construction, and we are not getting very deeply into that. It is something on which we do not have a great deal of information, but a limited number of flats will not affect the strength of mass concrete, provided the flats themselves are sound.

N. F. HOPKINS: What would be the effect on reinforced concrete?

P. J. FREEMAN: We do not know. We do not feel that a reasonable amount of flats (perhaps five per cent.) will damage any kind of mass concrete. I think it is asking a little too much of the Committee to get down to that right now. We have to leave something to you engineers to pass on. But we do say thin and flaky pieces, and the engineer may fall back on that. If somebody will give us something definite we shall be glad to include it.

C. S. DAVIS: As far as the actual wording of the paragraph is concerned, the engineer can reject this aggregate if it contains any thin and flaky pieces. It is up to the ruling of the engineer in charge of the work.

C. L. MCKENZIE:* The slag producers have no criticism to submit. It seems to be a practical and a workable specification.

J. A. FERGUSON: In a number of committees with which I have been connected we have found that the specifications regarding the weight per cubic foot for slag is more or less harmless. On an average it might be well to keep this requirement, because it is quite customary to put these specifications in, for, ordinarily, any good crushed slag will weigh at least 70 pounds.

C. L. MCKENZIE: I do not wish to be understood as accepting for the slag people as a fact the idea that you can not make good concrete with slag that weighs less than 70 pounds. I know you can. But 70 pounds for the graded aggregate is a practical standard to reach, and there is no purpose in objecting to it.

*President. Pittsburgh Construction Co., Pittsburgh.

P. J. Freeman: Many specifications are written just the reverse of these, but the Committee's reason for having "retained" instead of "passing" is that it enables you to use the fineness-modulus method if you care to; and, therefore, your specification could be compared directly with the report of the laboratory.

P. W. Price: It certainly calls for a well graded aggregate—there is no question about that.

P. J. Freeman: I may say in explanation of this paragraph that we are getting into a phase of the subject that has only been worked over in the past few years. There is not a great deal of data available, but there seems to be enough to make it conclusive that for limestone it is absolutely necessary to know that the stone is sound. Some limestone which we have in this district, called bastard limestone, will disintegrate in moisture, although it will last all right until it is blasted out. Such limestone in concrete will undoubtedly prove unsatisfactory. The evidence seems to be that if it passes five tests, as recommended here, the limestone will be durable. It might be 2 or 3 or 10, we simply adopt five, which is equivalent to perhaps from 25 to 40 natural freezings and thawings under severe conditions. We include slag with this, not because we have any particular data to indicate that such a test is really necessary or valuable, but from the data which we had, most any ordinary slag will meet it, and it is included because we felt it is a good thing to do.

Coming to the next test for gravel, this test is not recommended, for the reason that we do not know enough about it. There are a number of tests being run now on the soundness of gravel, and you can see that where you have many large and small pieces it would be difficult to pick out a representative sample of gravel. That is not the case with limestone under present conditions, so we are leaving that up to the engineer.

Tracy Bartholomew:* It is certainly desirable to provide a test which will differentiate between those aggregates which will resist freezing and be entirely satisfactory in service and those aggregates which will not resist freezing and will not be satisfactory in

*Industrial Fellow, Mellon Institute of Industrial Research, Pittsburgh.

service. The proposed test has been highly satisfactory in distinguishing between sound and unsound crushed-stone aggregates. We are now providing for the acceptance or rejection of slags by the same test; but concrete made from crushed stone or slag is subjected to no more severe freezing than concrete made from natural or crushed gravel. All four of the coarse aggregates recognized in these specifications should be capable of passing the soundness test and should be submitted to it if all are to be considered equally acceptable for use in concrete where permanence is expected.

V. R. Covell: Mr. Freeman touched on that. Limestone all comes from the same mass of rock and, therefore, is fairly uniform, as is true of slag; but gravel comes from rock formations ranging over many miles, and there are all sorts of materials. The difficulty is to select a fair sample.

P. J. Freeman: There will be such a test some day, but we do not know how to handle it at present.

Tracy Bartholomew: Slag aggregates are not uniform either —at least as regards porosity. Individual pieces may vary from quite porous to extremely dense; but each piece is composed of the same material in the same fundamentally sound condition.

P. J. Freeman: It is the Committee's understanding that it would be, and we are not inflicting any hardship on the slag, and there have been a considerable number of tests run. We do not have as much data as we have on limestone and the Committee does not insist on its being included.

The paragraph on abrasion embodies the standard abrasion test that has been used twenty-five or thirty years, originated in France, and which is the test of practically all limestone producers making a good product. The Pennsylvania State Highway specifications and Allegheny County do not permit more than five per cent. Six per cent. is a very satisfactory and safe specification. The same applies to toughness. The average of the specifications of various state highway departments is given in this paragraph, so we are not taking any radical step at all, and the Committee feels that it should not give a

great deal of attention to highway construction. We may want to add some other tests, but the Committee feels that these two are sufficient for all local purposes.

E. V. Braden: Did the Committee consider the use of these aggregates as specified, in concrete of various strengths? Does the Committee have any data on that subject? I think the Committee ought to be continued. It has turned over a workable set of specifications and it may be that it can help us along in getting specifications for concrete of various strengths which will include these specifications for local aggregates.

C. S. Davis: I think I speak for the members of the Committee that we appreciate your expression of thanks for the work we have done, and we would feel more complimented if these specifications as now adopted would be put into use by the membership. If they are not used, we will feel that our efforts have been wasted. It is up to the Society to show us whether our work is of any value or not.

E. V. Braden: Did you consider the use of these aggregates in designing concrete of different strengths?

C. S. Davis: I do not think that any engineer engaged in the making of concrete can very well avoid doing so. The writing of specifications for concrete involves the specification for the aggregates. This specification for aggregates is only a small part of the work of making concrete. If we have these specifications for aggregates, and if these specifications are perfect, there are about a hundred chances to one of making poor concrete. There are so many elements that go into the making of good concrete that this is only a small factor.

J. A. Ferguson: The members of the Committee, no doubt, have formulated in their own minds a procedure which they think would be appropriate after this report has been accepted. It is customary in the American Society for Testing Materials for the Chairman of the Committee to indicate whether he has anything further in view for the work of the Committee and to make a recommendation as to whether or not the Committee should be continued for the purposes

he has in view. I think, therefore, that it would be proper for us to hear from Mr. Davis as to whether he has anything in view for his Committee.

C. S. Davis: I will speak candidly on that subject. The work on aggregates has brought before us most emphatically the various questions of making concrete, and this work to be made a success should be continued and a specification for concrete drafted. That will involve a large amount of work, and I can not speak for the various members of the Committee as to whether they wish to continue or not. That has not been discussed by the Committee.

GAS SCRUBBING IN THE STEEL INDUSTRY*

By W. J. McGurty†

The several gases used in this industry for both fuel and power requirements contain variable quantities of both solid and vapor constituents, the amount and character of which are dependent on the source and the conditions under which they have been generated.

Apparatus and processes have been devised for the removal of the marketable impurities—so called by-products—although in every one of the artificial gases there are still constituents the removal of which would enhance their utilization value.

Classified as to thermal values, we have natural gas, coke-oven gas, bituminous producer gas, and blast-furnace gas, comprising the group usually associated with iron and steel plant operation.

Natural Gas. The natural gas of the Pennsylvania and West Virginia fields carries from 0.2 to 0.5 gallon per 1000 cubic feet of the paraffin hydrocarbons found in gasoline. The recovery of the gasoline content is usually effected by absorption in mineral seal oil, and in various types of absorbers, horizontal, vertical and mechanical.

Those of the vertical type (towers) are packed with various materials and some combine both bubbling and scrubbing action in the same shell.

With the advent of the mechanical absorber in this service, it has been possible to operate with reduced volumes of absorbent oil, at the same time securing a greater yield of the higher tension hydrocarbons such as butane, which when compressed makes a good cutting gas owing to its high thermal values, 3274 B.t.u. per cubic foot.

The gradual depletion of natural gas has been responsible for the rapid development of the by-product coking industry, with conservation of the former immense wastage of the gas and its valuable by-products during bee-hive operations.

Coke-Oven Gas. The crude oven gas entering the plant distributing system contains variable amounts of impurities, dependent on the type of coal carbonized and the temperatures and pressures maintained during the coking period.

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†Sales Engineer, Bartlett Hayward Co., Baltimore.

Tar removal equipment follows the primary coolers, and while the static type is largely used, the removal of the tar content by recirculation of tar in the mechanical scrubber has been satisfactorily demonstrated. In this method, maintenance of the tar at a temperature above the dew-point of the gas assures a drier product, and permits operating temperatures exceeding that necessary for satisfactory operation of the static type, with the gas retaining more of its higher oils than in the latter case. This means of removal would eliminate some of the steps in the process of direct ammonia recovery, which are necessary in conjunction with static operation.

In some of the coking operations, the ammonia is recovered by water scrubbing with the production of a weak ammonical liquor which is worked up into both concentrated liquor and sulphate, depending on the comparative marketing conditions for these products. The strength of this solution will range from 5 to 15 grams per liter depending on the type of equipment engaged in its removal.

There is some removal of both CO_2 and H_2S due to interaction between them and the ammonia, the purifying effect naturally depending on the intimacy and time of contact as well as the strength of solution secured with different types. In one type, a double functioning of gas cooling and ammonia absorption is effected by dividing the operation into two stages. Recirculated, cooled, weak liquor in the first stages precipitates tar and naphthalene with a consequent improvement in the quality of the solution obtained in the absorption stage, and the elimination of the main difficulties in indirect cooling operations.

The saturator of the direct process is, in effect, a scrubber wherein the gas is subdivided into a number of jets by means of the slots in the cracker ring, the total slot area varying with the total volume of gas to be treated. Due to the elevated temperature in this process, the gas will pick up additional water vapor which involves final cooling to prevent emulsification of the oil used in the light oil scrubbers.

Removal of the light oil content and its preparation for use as motor fuel completes the usual series of by-products recovered in coking operations.

Mineral seal oil, of special characteristics as in the case of gasoline recovery, is employed for this purpose and the usual practice secures saturations of from 2.5 to 3.5 per cent., the variations usually

following variations in oil and gas temperatures during absorption. Tower washers with grids for packing, operating in series of two or more units, are usually employed in this country for this recovery and during the past several decades there has been but slight modification of design.

In removing soluble vapors each of which possesses varying vapor tensions, such as ammonia or the various hydrocarbons, it is essential for both good recovery and high concentration that the solvent be maintained at as low a temperature as is economically possible. The latent heats of such vapors induce a considerable heating of the solvent, the extent of which will vary with their initial content in the gas, and with such increase in temperature the increased tension sets up an equilibrium between gas and solvent earlier than if cold. The installation of internal water-cooled coils in one type of mechanical scrubber has in the same operation effected a 33 per cent. increase in the concentration above what would be secured if this provision were not made.

At one of the plants in this district the removal of hydrogen sulphid from the gas used for furnace heating, has been of advantage in improving the quality of the steel. This operation consists in scrubbing with a solution containing both carbonate and bicarbonate of soda, the H_2S forming principally a hydrosulphid with some fixed salts. Regeneration of this solution permits its recirculation, and with further development the sulphur is recovered in solid form.

Depending on both temperatures and pressures in the carbonizing chamber, from 0.7 to 1 pound of cyanogen per ton of coal may be produced, and its removal would also remove a considerable depreciation factor in plant equipment and the distributing system.

Ferrous sulphate, or copperas, in the presence of ammonia is an active extractive medium for this material, forming an insoluble ferrocyanide of iron and ammonium. This would afford a means of disposal of some of the pickling liquor and by utilizing the free acid content of this liquid reduce the amount of acid needed in the ammonium sulphate process. The ammonium sulphate produced in the reaction between the copperas and cyanogen would amount to approximately 50 per cent. of the iron compound in weight.

Conversion of the insoluble ferrocyanide to other compounds, or its return to the ore pile for recovery of iron would still take care of two problems and show a credit to general operations.

Where the gas is to be transported for any distance, the removal of both excess water vapor and naphthalene by thorough scrubbing would aid in the distributing operation.

Producer Gas. Raw producer gas used in mill operations is generally used without any treatment for removal of the tars, ammonia, and carbon content.

Transportation of this gas involves the use of lined mains of large size to take care of the carbon deposits which result from successive condensation and redistillation or cracking of the tar. To keep the mains open, frequent burning-out of deposited carbon is necessary, with a consequent loss of the thermal value of this material.

Producer-gas tar, naturally of high carbon content, has readily responded to treatment when the temperature of the outlet water is 95 to 100 degrees F. as at this temperature it remains fluid and not "sticky" or plastic. This involves the use of reduced volumes of water in order not to chill the tar, and the mechanical scrubber has reduced the tar content of hot, raw gas by 97 per cent., in one operation. Removal of the tar close to the producer would prevent its degradation and the subsequent loss of carbon. A saving in the cost of the piping would likewise be effected.

Blast-Furnace Gas. The blast-furnace is essentially a huge gas-producer with the constitution of the outgoing gases varying with the character of the raw materials charged, and with the thermal and chemical reactions occurring during the reduction of the ore.

The gaseous constituents and thermal value of the gas are directly affected by the coke rate per ton of product, and this factor as well as temperatures and pressures in the several reaction zones also influences the character and quantity of the solids carried in the gas. These solids consist of the finer particles of all materials in the burden together with "fume" and sublimates of the alkalies and metals, most of which in average practice in the northern United States are in the solid phase when leaving the furnace. In the reduction of ferromanganese there is a larger quantity, as well as a greater proportion of "fume" in the vapor phase due to the higher operating temperatures. These products have been aptly termed "metallurgical smoke." The first step in their removal is the condensation from the vapor to the solid state.

Compared with lake ores there is from three to seven times as much potash in manganiferous ores, with southern ores carrying from two to six times the content of lake ores. The "fume" problem is consequently increased in pig-iron production in the southern district and a greater depreciation factor in the life of refractory materials is a result.

While the insoluble dust recovered in wet scrubbing will show as much as 90 per cent. passing through a 200-mesh screen, the particles of sublimates are even smaller. The emulsifying effect of this combination militates against the effective use of the gases of high calorific value in which they exist causing at times suspension of combustion under certain furnace conditions in both pig-iron and ferromanganese operations. The solids existing in blast-furnace gas as well as the vapor constituents recovered from the other gases are present in proportions representing but a few tenths of one per cent. of the total weight of the gas. Satisfactory removal requires extreme penetration of the gas stream carrying either or both types of constituents, as it is impracticable from the operating standpoint to subdivide the gas into innumerable streams, and the gradual development of scrubbing equipment has been toward breaking up the liquid into as minute particles as possible in order to present the maximum amount of liquid surface with a consequent increase of penetration and intimacy of contact. The most effective removal of both vapors and solids is secured when the actual contact is at low gas velocity, since solid particles of light density can be wetted, weighted, and more easily precipitated in this case.

The greatest proportionate removal of insoluble dust particles is at the inlet zone where both gas and water are hottest, and where the steam flash due to the transition from superheated to saturated gas takes place thereby reducing the surface tension of these particles and effecting a more thorough wetting of them.

The alkaline fume products are water soluble and consist of both chlorid and sulphate combinations, with their solubility varying with both temperature and penetration.

Recovery data developed in connection with the scrubbing of ferromanganese gas indicate an appreciable return from the by-product potash produced. The initial alkali content and the tonnage handled would be the determining factors in pig-iron operations.

In his investigations at Bethlehem several years ago, R. J. Wysor demonstrated that almost 70 per cent. of the potash produced was in the furnace gas and therefore available for recovery in the scrubbing system. Such a product would have a high value as fertilizer material, so that it is possible by modern scrubbing treatment to eliminate with profit one of the serious handicaps to the effective use of furnace gas in the various types of combustion equipment.

Combustion is purely a chemical reaction consisting in the oxidation of either solid or gaseous carbon compounds with the evolution of heat. Like all such reactions, its intensity and rapidity are affected by the degree of dilution of either agent in the combination. The resultant, or so-called "flame temperature," is the temperature at which the total heat content of the products of combustion of one cubic foot of gas is equivalent to the net heating value of the same cubic foot of gas contributing to the reaction.

While calorific values are often calculated from the volumetric analysis of a gas, the standard method for such determination is by the calorimeter, thus giving actual rather than problematical values.

The flame temperature of any given gas is affected by:

1. Heat losses due to excess air which must be heated to this temperature with a consequent reduction in the available heat.

2. Losses due to either physically entrained moisture or aqueous vapor, or a combination of both, which must likewise be heated to the flame temperature.

3. Losses by radiation, etc., induced by foreign particles carried in the gas.

Under certain conditions there is a loss due to dissociation of both CO_2 and water vapor. It is therefore logical to assume that the flame intensity is dependent on the rapidity of oxidation of the carbon.

Most of us remember that household panacea, cod liver oil, which to satisfy the victim had to be "tasteless." This was accomplished by emulsification or wrapping each little vitamine in a blanket of mucilage which added to the burden of the digestive organs. Times have changed and now young America gets his vitamines straight from pedigreed codfish and gets more per spoonful.

From the viewpoint of both chemistry and common sense, which is the more effective—a "tasteless" B.t.u. wrapped in a wet blanket of dirt and fume, or a "pedigreed" B.t.u. ready to react as soon as it gets the oxygen?

If to assure successful operation of a gas-engine, it must be supplied with gas of a quality superior to the air that its operator breathes, is it not reasonable to expect a higher efficiency of stove and boiler through removal of the waste materials?

Within the past decade there has been an alarming falling off in the supply of gaseous carbon, or natural gas, which Providence had lavishly bestowed on this district, and various estimates of our solid carbon resources have not been reassuring.

While various processes and methods will ever be devised for the more direct reduction of iron, a more efficient operation of the auxiliaries now at hand and a more effective utilization of the potential resource existent in blast-furnace gas, through more modern methods of preparing it for its various duties, will result in a conservation program worthy of the greatest industry of modern times.

DISCUSSION

S. R. Bellows:* Which was developed first; the mechanical scrubber or the hot scrubber, and how do they differ?

W. J. McGurty: I presume that you refer to one of the wet-type dust catchers. About the first development beyond the dry dust catcher was made by Bachman at Port Henry, N. Y., where a water film was used on the inside of the shell. Following this came the Mullen washer in which the gas is forced through a number of pipes, and impinges on the surface of the water maintained in the cone bottom.

The hot scrubber was first in this service. The mechanical scrubber is an apparatus in which the water is distributed through the gas stream by means of a rotating element which causes it to be broken up into minute particles that travel at very high velocity.

F. W. Sperr, Jr:† I think it would be very interesting if Mr. McGurty could give us some of the details of actual operation of the mechanical scrubber on blast-furnace gas; that is, in regard to water consumption, etc.

*Engineer, Blackstone Mutual Fire Insurance Co., Providence, R. I.
†Director of Research, Koppers Co., Pittsburgh.

W. J. McGurty: We have scrubbers operating in both the northern and southern iron districts. In the latter operation the temperature of the raw gas entering the scrubber is several hundred degrees higher than the gas from the ores used in this district. This temperature is above 500 degrees F. and the gas leaves the scrubber at a temperature of about 10 degrees F. above that of the incoming water. The water supplied is regulated by means of a thermostatic control and with any variation in gas volume there is a proportionate change in the water volume.

The average dust content over a test period of several days in one plant was approximately 4½ grains per cubic foot in the raw gas. This was reduced to as low as 0.02 grains with an average of 0.07 grains per cubic foot for daily tests extending over several months.

The total dust tonnage from a 500-ton furnace operating on lake ores was around 24 to 26 tons a day.

F. W. Sperr, Jr: How many gallons of water do you use?

W. J. McGurty: The quantity will depend on its temperature as well as the temperature and aqueous vapor content of the raw gas. In one plant, the average rate during nine months of both summer and winter operation was 17 gallons per 1000 cubic feet of gas.

S. R. Bellows: What are the prospects for effectively scrubbing producer gas from relatively high sulphur coals so that it makes suitable gas for use in the iron and steel industry. For example, our low sulphur coals are gradually becoming scarcer. We are driven to use coals somewhat higher in sulphur, and a problem of the future will perhaps be to remove some of the sulphur from producer gas. Is there any hope of doing that economically?

W. J. McGurty: I think that the liquid purification process developed by the Koppers Company for sulphur removal offers the most economical means of purifying this type of gas. The tar, however, must be removed prior to the purification process, as it becomes very viscous when in contact with cold liquid.

Bituminous producer-gas manufacture has been abandoned in several plants on account of the high cleaning cost and difficulties due to

stoppages of this plastic material in the tower-type washer. With water temperatures below 90 degrees F., which is the case in tower-washer operation, the tar is very difficult to handle, while above that temperature it is fluid and will float. The mechanical scrubber uses much less water in the cleaning of this gas, with a consequent increase in the temperature of the outlet water so that it is easy to maintain the proper fluidity in the tar.

S. R. Bellows: I should like to ask how this tar collects. Does it run back into the tar tanks?

W. J. McGurty: The scrubber effluent runs to a separating tank which is provided with means for warming up the settled material if necessary to enable it to flow to the storage well. It can be used in the boiler plant, and the gas-cleaning plant credited with the cost of replaced fuel.

Our development of this operation was in a glass factory that had to replace natural gas with producer gas. The use of raw gas in the lehr would have required a cleaning or polishing of the glass before cutting it. The scrubbing results had to be and were very efficient, the cleaned gas giving a very satisfactory operation.

S. R. Bellows: Is there much tar in producer gas?

W. J. McGurty: There is not as much in producer gas as in coal gas, and as the gas is generated at a higher temperature the tar is heavier.

E. P. Jump:* Can you tell me just exactly what is done about the potash in blast-furnace gas?

W. J. McGurty: In washed gas the potash will go into solution with the scrubbing liquid.

E. P. Jump: I have noticed occasions where washed blast-furnace gas will not burn, or burns with great difficulty and gives little heat.

*Test Engineer, Carnegie Steel Co., Duquesne, Pa.

W. J. McGurty: It depends on how well it is washed. The tower washer will not hold back slips in the furnace, and that is about the only time in northern pig-iron operation that much "fume" will be produced in the furnace. I was in one plant, however, where they were using an ore containing 0.25 per cent. of potash and a high coke rate where there was considerable "fume" leaving the stove stacks most of the time.

E. P. Jump: Then you mean to say that as far as you know there is no potash present in washed blast-furnace gas that could have a deleterious effect on the gas.

W. J. McGurty: Not if it is thoroughly washed. I spoke of the "fume" as consisting of both alkaline and metallic vapors. There are times when both manganese and iron vapors, perhaps carbonyl compounds, are produced in the furnace, and, as the gas cools, some of them will condense to very finely divided solids, which might be present in sufficient quantity to put out the flame. Following Mr. Wysor's potash investigations at Bethlehem, this matter was discussed and he stated that very finely divided table salt blown into a clean gas flame would put it out. It is therefore a mechanical action.

G. M. Kirkpatrick:* I would like to ask if any calculation has been made as to the number of contacts the oil makes with the gas in the case of a natural gasoline absorber.

W. J. McGurty: Depending on the gas volume and oil rate, we have estimated from 90 to 140 contacts.

G. M. Kirkpatrick: About what percentage of saturation can you get?

W. J. McGurty: About 10 per cent. as against about 2½ per cent. with the same gas and absorbing oil in tower absorbers.

G. M. Kirkpatrick: Do you use interstage cooling coils?

*Sales Engineer, Andrews-Bradshaw Co., Pittsburgh.

W. J. McGurty: Yes, internal cooling coils located at the point where the actual scrubbing takes place, so that the oil or other absorbent is kept cool and consequently more effective.

G. M. Kirkpatrick: Are the cooling coils located in the reservoir between the rotating element and the side wall?

W. J. McGurty: Either in the reservoir that supplies the rotating element or on the baffle on which the spray impinges. The latter is the normal practice, as the wiping action of the high-velocity spray gives better cooling than if located in the basin itself.

G. M. Kirkpatrick: Colonel Burrell in his book on "Recovery of Gasoline from Natural Gas" shows a picture of the spray in the mechanical scrubber, and this indicates that the oil is broken up into a very fine mist. Is the velocity of the gas through this mist sufficient to cause entrainment of the oil?

W. J. McGurty: We have scrubbers operating under as much as 75-pound pressure, on dry natural gas. In some southwestern operations, where the gasoline content will run as high as two gallons per thousand feet, and with high oil rates used, there are no oil losses in the residue gas.

G. M. Kirkpatrick: Another question occurred to me on the producer-gas problem. You speak of the necessity of cleaning the ordinary filled type of tower owing to accumulation of plastic material. In the Feld scrubber how do you prevent this accumulation, assuming you get a fine material, which you do, and that the velocity of the vapor is relatively lower?

W. J. McGurty: The liquid velocity is much higher than in tower washers as there is no recirculation in the latter. The temperature of the liquid is the deciding factor as to whether the tar will flow or stick, and at temperatures below 90 degrees F. there is a tendency even in the mechanical scrubber for it to adhere to the shell. The high velocity of the rotating element would prevent its adhering on this portion of the mechanism.

G. M. KIRKPATRICK: I understand then that you have some adhesion on the side walls and on the coils, but this is not rendered serious owing to the fact that you use a higher rate of liquid circulation?

W. J. McGURTY: Yes, to get a scouring effect.

G. M. KIRKPATRICK: Is the rate of circulation higher than in the case of a filled tower?

W. J. McGURTY: Yes, because in that case the liquid is falling and will flow one way or another, depending on the position of the filling or packing.

G. M. KIRKPATRICK: The plugging in a filled tower would neutralize the low velocity?

W. J. McGURTY: Yes; also too cold a liquid.

G. M. KIRKPATRICK: Some years ago, while talking with a man connected with the Pennsylvania Salt Company, some statements were made with which I was not in entire agreement at that time. One of them was to the effect that with the mechanical type scrubber you get a very fine mist. You break the liquid up into extremely small particles. Is that true?

W. J. McGURTY: The first operation we had where "fume" was handled was on the furnace gases from copper smelting at Ducktown, Tenn., in the Copper Hill district. The solids were principally zinc oxid in a finely divided form, and it was carried and deposited over a large area with considerable damage. A cubic foot of this dust weighed about 312½ pounds, with about 2½ pounds per 1000 cubic feet present in the gases leaving the furnace. It was evidently a very fine sublimate, and, calculating the relative size of the water particles, there were apparently about sixty particles of water to one particle of "fume" in that operation.

G. M. KIRKPATRICK: That brings up the point again of the carrying over of liquid.

W. J. McGurty: This is taken care of effectively by the wiping action of the gas against curved plates, which collect and precipitate such entrainment as takes place. These plates were developed in experimenting with fine dust particles, and have worked very well in the handling of finely divided water particles.

G. M. Kirkpatrick: How does the efficiency of a mechanical-type scrubber compare with that of the Cottrell precipitator used with smelter gas?

W. J. McGurty: According to published results, the outlet gas carries less dust from "wet" scrubbing than from the "dry" types of cleaner. These results were in the Colorado Fuel & Iron Corporation's operation of the electrical precipitator.

G. M. Kirkpatrick: That was in connection with the mechanical type and the Cottrell type?

W. J. McGurty: The outlet gas carried about 0.3 grain per cubic foot over all tests, while our average was 0.06 to 0.07. I have not seen a report on any other installation of the electrical type.

L. E. Riddle:* I do not believe that potash is the reason that blast-furnace gas burns poorly at times. In making ferromanganese we have a gas which contains as much as 11 grains of dust per cubic foot; this dust contains about six per cent. potash. At times we get a condition in the gas known as "calico" gas, and when it can not be kept burning at the nose of the burners even with the aid of oil and waste or other large pilot fire, we have proved that this is not because of the potash, cyanides, or other chemicals in the gas, but because of the extra large amount of suspended dust particles. We have been able to by-pass a small amount of this gas at a time when it would not burn in the burners and filter out the dust, and the clean gas burned beautifully. Analysis of the dust showed that these conditions arise regardless of the different elements contained in the dust, and, therefore, we feel that it is entirely due to the solids in the gas.

In one type of washer the cones are perforated; in some of the

*General Superintendent, City Blast Furnaces, Carnegie Steel Co., Pittsburgh.

others, where the cones are not perforated, all the water is thrown off the periphery of the cone. Being early in the field, you no doubt experimented with different kinds of cones. There has been a good bit of discussion as to which breaks up the water to the better advantage. Which do you think is the more efficient method?

W. J. McGurty: We have, naturally, made experiments with various types of cones, with all sorts of edges, and for the past decade have built the perforated type, which has proved to be the most efficient in every respect. There is a primary breaking up of the water on the cone itself, in addition to that secured by impact on the shell, and a much finer spray is produced with the perforated type than with any other development.

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Wm. Penn Hotel, Tuesday, June 15th at 4:15 P. M., V. P. John A. Hunter presiding, in the absence of the President, Messrs. Clifford, Hopkins, Covell, Rice, Humphrey and the Secretary being present.

The Minutes of the last regular meeting held May 18, were approved without reading.

Applications for membership from the following gentlemen, having been published to the Society, pursuant to the action of the Board, were elected to membership.

MEMBERS

Brown, George N.	Starr, Clarence T.
Howe, Wm. C.	Sheets, George DeWitt
McGannon, Frank Edward	Hoeveler, John A.
Marsh, Burton Wallace	Wood, Douglass

ASSOCIATE MEMBERS

Bowers, Paul E.	Hinderer, Howard L.
Bamborough, M. A.	King, Floyd E.
Allen, James G.	Kiefer, Lewis J.
Guthrie, James McMurchie	Huber, Louis Steele

Applications for membership were received from the following gentlemen and their names ordered published to the Society. Assignment to the various grades of membership is as follows:

MEMBERS

Dyche, H. E.	Bennett, George Lewis
Hughes, I. Lamont	Waldorf, Fred

ASSOCIATE MEMBERS

Stuart, Gordon W.	Worthington, E. L.

JUNIORS

Hilton, Winfield Reed	Hoffman, James Thomas

Smyers, William H.

Application for transfer was received from Mr. D. M. Reese and after discussion, the Secretary was requested to advise him of his transfer to the grade of Member.

Letters of resignation were received from the following gentlemen and after discussion, they were accepted.

Moyer, W. I.	Hannah, Thomas

The Secretary reported the death of the following members:

D. M. Howe............................	Joined Feb., 1902	Died June 2, 1926
M. F. Newman........................	Joined Mar., 1912	Died May 25, 1926

The report of the Secretary showing the condition of business May 31st, having been audited by the Finance Committee, was approved.

The report of the Entertainment Committee was presented by Mr. Clifford, who stated that final arrangements had been made for our Annual Golf Tournament, the first game of which will be played at Shannopin Country Club, Friday, June 18th. The Committee will hold no other activities during the summer months, but will probably hold inspection trips and other social functions in the fall.

Mr. Hunter, Chairman of the Finance Committee, reported that in accordance with action taken at the Board meeting, the Committee had purchased $6000 worth of bonds as follows:

Two Wheeling Steel Corp. 5½s at 96, two McKeesport Tin Plate Company 6s at 101½, two Baltimore & Ohio R. R. 5s at 97. The total expense of these bonds was $5965.17. These bonds have been placed with our other Permanent Fund bonds in the Safety Deposit Box of the Pittsburgh Trust Co.

Mr. Weldin, Chairman of the House Committee, reported an evening attendance of 356 for the month of May.

In the absence of Mr. Affelder, Chairman of the Membership Committee, the Secretary reported that one meeting of the Committee had been held to assign applications received since the last meeting of the Board.

The Secretary reported verbally on his trip to Detroit to attend the Conference of Local Society Secretaries held under the auspices of the American Engineering Council and stated that they had a very interesting and instructive meeting.

The main subject for discussion was the possibility of a standardization of local society membership requirements with the ultimate aim of an interchange of memberships. The Secretary served on the special committee appointed to go into this matter and it was found that the requirements of our Society were the second highest among the local societies, the Western Society of Engineers being the highest.

Other matters discussed were the relationship between local sections and national societies; the establishment of student branches; and the general conducting of the details of the local organizations.

The meeting adjourned at 5:15 P. M.

K. F. Treschow, *Secretary.*

JOINT MEETING OF THE MECHANICAL SECTION ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA AND PITTSBURGH SECTION AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

The regular bi-monthly meeting of the Engineers' Society of Western Pennsylvania was held jointly with the Pittsburgh Section of the American Society of Mechanical Engineers, June 1st in the Blue Room, William Penn Hotel, at 8:20 P. M., Chairman Wm. Shaw presiding, 25 members and visitors being present.

The Minutes of the last meeting held April 15th, were read and approved.

No further business coming before the Section, the paper of the evening on Furmanite, Its Uses and Advantages, was presented by Oliver L. Gilbert, Sattley & Gilbert, Sales Agents, The Furmanite Corporation, Newport News, Va.

On motion, a vote of thanks was extended to the author for his very interesting paper.

The meeting adjourned at 9:18 P. M.

K. F. Treschow, *Secretary.*

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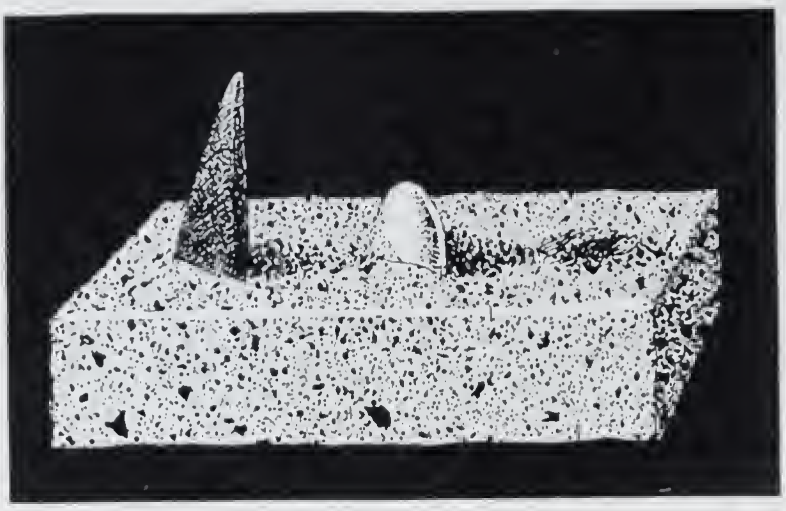
PROFESSIONAL CARDS



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PROCEEDINGS

OF THE

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA

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Incorporated 1880

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American Institute of Electrical Engineers. Journal

American Machinist

American Roofer

American Society of Civil Engineers. Proceedings

American Society of Mechanical Engineers. Journal

American Society of Naval Engineers. Journal

American Welding Society. Journal

Arkitektur

Association of Chinese and American Engineers. Journal

Association of Iron and Steel Electrical Engineers. Journal

Blast Furnace and Steel Plant

Boston Society of Civil Engineers. Journal

Builders' Bulletin, The

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Chemical Age, The

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Coal Trade Bulletin

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Electric Railway Journal

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Electrical World

Eliktrische Kraftbetriebe u. Bahnen

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Engineering Institute of Canada. Journal

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Engineering Production

Engineering Progress

Engineering and Contracting

Engineering and Mining Journal

Engineering Review

Engineers and Engineering

Engineers' Club of St. Louis. Journal

Explosives Engineer

Feuerungstechnik

Finance and Industry

Forging and Heat Treating

Franklin Institute. Journal

Gluckauf

Great Britain—Patent Office. Illustrated Official Journal

Heating and Ventilating Magazine

Industrial Management

Institution of Mechanical Engineers. Journal

Institution of Mining Engineers. Transactions

Iowa Engineering Society. Proceedings

Iron Age

Iron and Coal Trades Review

Iron Trade Review

Journal of Industrial and Engineering Chemistry

Journal of the United States Artillery
Keramische Rundschau
L'Association des Ingeniurs. Annales
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New England Water Works Association. Journal
New Zealand—Patent Office. Journal
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Professional Engineer
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Railway Club of Pittsburgh. Proceedings
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Royal Society of Arts. Journal
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Sanitary and Heating Engineering
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Sheet Metal Worker
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Western Society of Engineers. Journal
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HIGHWAY LOCATION AND CONSTRUCTION*

By S. W. Jackson†

A highway, as we know it, is a strip of ground dedicated to and controlled by the public for the purpose of carrying on transportation and communication. In discussing highway location we refer to the entire width, including all that portion used by vehicles and beasts of burden, known as the roadway proper; the ditches, gutters and all necessary drainage structures; sidewalks, if provided, and any adjacent ground within the right-of-way limits.

Much of the highway improvement that has been completed to date is more or less of a superficial nature and has been dictated principally by the emergencies and exigencies of the time, without the seasoned thought and study that work of such importance and magnitude is entitled to receive. In other words, we have been sacrificing the future to meet temporarily the present demands. The futility of pursuing such a course is evident, and has been indicated during the past few years by the extensive relocations and revisions that are being made in connection with the reconstruction of highways that were improved during the past two decades. Highway location and reconstruction are following largely the same course that was pursued by the railroads of this country. It is imperative that we profit by the errors and extravagances which they experienced and which we have noted in our own location work to date.

It is common practice to refer to our high-type modern pavements as permanent, but this, as we know, is a misnomer, as we have neither been able to construct, nor is it likely we shall be able to build, a permanent pavement. Of course, there is always the opportunity, through scientific design and more efficient construction, to provide a pavement that will withstand the wear and tear of traffic and the action of the elements much longer than our best pavements of to-day. The location of a highway, however, may be considered as the most permanent part of it, and the degree of permanency may be controlled to a large extent by the wisdom and foresight shown in its selection. Future developments, which can not reasonably be foreseen nor anticipated, may at some time necessitate or warrant further

*Presented May 4, 1926. Received for publication July 3, 1926.

†Division Engineer, Pennsylvania Department of Highways, Greensburg, Pa.

modification or revision of the location. More or less private development generally follows the improvement of any particular section of highway. If the location adopted be unsatisfactory for economic road operation, both the original highway investment and the private investments are often a total loss, as they may be of little or no value when the location later is changed. Consequently, the economic location of our highways is the most important problem facing the highway engineer to-day.

There was comparatively little interest in highway improvement in the rural sections of this country previous to 1900. Highway improvement in the first few years after that date was active only near the larger centers of population. The traffic to be accommodated was mostly horse drawn, and there was little demand or justification for the expenditure of large sums to improve the alignment or to adopt better locations involving extensive grading. As the use of motor vehicles became more common and widespread, the demand for improved roads increased by leaps and bounds. There was, however, such a small percentage of our highways improved that the crying demand was for the early improvement of a large mileage with some type of surface that would meet the existing requirements for the use of the rapidly increasing number of motor vehicles which were appearing on our highways. While minor revisions in location were made to improve dangerous and unsightly alignment, comparatively little effort was made to select locations that would economically meet the demands of the traffic that faces us to-day, and the demands of the increased traffic that we may anticipate in the next ten or twenty years.

Highway engineers and others directly interested in road improvement had sensed for many years that better and more direct roadways must be provided, but the public at large was not sufficiently impressed with this matter to provide the necessary legislation or finances. It required an international catastrophe to awaken our citizens to the full realization of the importance of providing promptly more and better highways than we had constructed in the past. In 1917 and 1918, when this country was suddenly called upon to equip and place in the field an army aggregating four millions of men, our public for the first time realized the importance and value of a comprehensive system of improved highways. Our railroads were not able to meet the demands, and our highways were called upon to

withstand the stupendous burden imposed by the hundreds of thousands of automobiles and war trucks that it was necessary to transport overland from the factories in the middle west to the sea-coast and intermediate points. Also, many of the products and necessities formerly shipped by railroad to nearby points had then to be transported by motor-trucks. The sight of great numbers of these heavily loaded vehicles, laboring over the unimproved highways, or by devious and roundabout ways following and literally churning to pieces the cheaply constructed pavements, was a very expensive lesson to our people. Possibly the awakening of the general public to the actual conditions and needs is sufficient recompense for the damage that was done and the delays that were encountered. Following the war, the state, county and other smaller units of government found it much easier to secure legislation and funds that would permit more leeway in locating highways and constructing better pavements.

During the early days of highway improvement in this country the securing of light and easy grades far overshadowed the question of alignment, and sharp turns and curves were not considered particularly objectionable. The popularizing of motor travel and transportation during the past few years has made it advisable and necessary, for safety, to eliminate kinks and sharp curves as much as possible, and, in many cases, to sacrifice or increase grades a reasonable extent in order to improve the alignment. In this state we are now expending considerable sums in eliminating and easing sharp curves, and revising unsatisfactory alignment on sections which were improved not more than ten or fifteen years ago. Marked examples of this work, with which users of the Lincoln Highway are familiar, are on the west slope of Laurel Ridge east of Ligonier, Grand View near the Somerset-Bedford County line, the triple reverse curves east of Schellsburg in Bedford County, and many other sections in Bedford, Fulton and Franklin counties, where the old improved road was considered dangerous and had been the scene of many accidents.

The large corporations of our country learned many years ago that it was not only advisable from a humanitarian standpoint to protect the lives and guarantee the safety of their employees by taking all possible safety precautions, but they found the expenditures in attaining such an end were also justifiable from an economic standpoint. As public servants, we must realize that we are directly accountable to

the public; and highway engineers are not justified in permitting hazardous location or design and balancing it in dollars and cents reckoned on the value of human limbs and lives. In these days, if there be an accident of consequence, such as a railroad wreck, mine disaster, or building failure, one or more public investigations are immediately started to determine and place the responsibility. Unless the highway engineer takes all possible precautions in locating and designing the highways to protect the traveling public, it will be only a question of time until strict legislation is passed governing such work and holding the highway engineer or official responsible for accidents due to faulty design or construction.

The highway which is to serve the public between certain points economically, all other things being equal, is naturally the shortest and most direct route between those points. Consequently, next to safety, directness is a prime requisite in the location of a through highway. The time element has become a very important consideration in the economic operation of motor vehicles. Time and distance are so closely related that, all other things being equal, one may be readily understood if expressed in terms of the other, and either or both may be evaluated in dollars and cents. To illustrate the importance of directness and the time element clearly, the speaker quotes the following from a lecture given by William H. Connell, Deputy Secretary and Engineering Executive of the Pennsylvania Department of Highways:

"The average motor transportation cost to highway users for each thousand feet over a hard surfaced road is approximately $0.023 for each vehicle. Therefore, the cost for one thousand vehicles a day would be $23.00, or $8,395.00 per year, or $167,900 for twenty years. Many relocations are made which result in shortening the distance more than a mile. Based on these figures, the saving to the users of each mile would be approximately $44,300 a year, or $886,000 for twenty years. These figures are based on 90 per cent. passenger and 10 per cent. truck traffic.

The relocations thus far in Pennsylvania have resulted in a saving of approximately one hundred miles. With an average traffic of one thousand vehicles a day, the saving in operating costs is approximately $4,430,000 per year. Adding to this $480,000 which includes the average annual cost of one hundred miles of pavement made up of interest on the investment, sinking fund requirements for bond issue, and maintenance costs, makes a total saving of $4,910,000 per year."

Directness, however, in the construction and improvement of

highways is largely influenced by the topography, such as hills, rivers and streams, soil conditions, landslides, and other natural features; also by man-created developments in that particular locality, such as buildings, railroads, connecting highways, etc., which restrict and more or less control the ultimate location. In Pennsylvania these conditions generally dictate the adoption of alignment with many curves. When the curves are of long radius, of say fifteen hundred feet or more, they are not particularly objectionable other than from a strictly commercial standpoint, where the deviation from a straight line increases the distance. In fact, from an esthetic standpoint—and this is of much importance in highway construction—it is well established that a reasonable amount of light curvature adds to the charm and interest of a highway. Where tangents in the location, either in the horizontal or in the vertical plane, aid materially in securing directness, safety, and convenience to both the traffic and adjacent property, they should be sought and established. Where they do not so justify themselves clearly, curvature should, as far as possible, be used to accomplish these results. Curves are objectionable where they obscure vision of traffic on the roadways to the point of danger; also, if, by their sharpness, they make the operation of traffic unduly difficult or dangerous at reasonable speeds.

The view on the inside of horizontal curves may be obscured either by vegetation or structures or by the slope in cut sections. A special act of the legislature authorizes the Secretary of Highways of Pennsylvania to control the growth of vegetation at points where it might prove a menace to traffic, such as on the inside of sharp curves or at road intersections.

Where the cut slope on the inside of horizontal curves with radii of less than 300 feet obstructs the view, it is the practice of the Pennsylvania Department of Highways to lessen the danger by cutting a horizontal bench in the face of the slope, thus providing a greater length of vision. Vertical curves are used at each point on the profile where there is a break in grade. The length of the vertical curve is governed by the algebraic difference of the adjacent grades, and in all cases should be sufficient to provide an easy riding surface and to furnish the necessary length of vision for reasonable speeds. This is especially essential at the summit of hills with steep descending grades.

The second objection—that in which the sharpness of the curve makes the operation of traffic dangerous—is met by superelevating or by superelevating and widening the roadway on such sections. On a horizontal curve without, or with insufficient, superelevation, vehicles tend to move in a direction tangent to the curve. On such curves the occupants of vehicles can not ride with ease and comfort, as muscular energy and effort are required to brace the body and overcome the centrifugal force. If curves be superelevated excessively, they are objectionable to slow-moving vehicles, especially at times when the surface is wet or slippery, when such vehicles tend to slip and slide to the low side of the roadway; consequently, it is advisable to select and use a rate of elevation per foot of width that will be safe for the vehicles moving at a reasonably high rate of speed; and, also, safe and convenient for the heavy and slow-moving conveyances. To conform with both, naturally requires a compromise. The present practice in Pennsylvania in elevating curves is as follows: There is no additional widening on roadways of 16 to 20 feet where the curve has a radius of more than 600 feet and less than 1000 feet. Superelevation, however, is provided by holding the established grade along the center-line of the pavement and by tilting the side forms to provide a slope of ½ inch per foot from the outside to the inside of the curve. The crown is left in the strike-off templet, which permits the use of standard equipment and methods in construction. Where the radii of curves are less than 600 feet the pavements are widened and spiraled on the inside and a straight slope is used instead of the parabolic crown. The widening on the inside of curves varies from two feet on a curve with radius of 600 feet to a maximum of eight feet on the sharpest curves. The superelevation increases from ½ inch per foot on curves of 1000-foot radius to a maximum of one inch per foot on the sharpest curves.

While our present practice in Pennsylvania is not to superelevate curves with radii over 1000 feet, we are now making studies and giving thought to elevating all curves with radii less than 2000 feet. The length of the curve also enters into the problem, and it is noted that the effect of the centrifugal force on the motor vehicle appears to increase with the length of the curve. There seems to be little justification for superelevating curves less than 100 feet in length.

For those interested in the procedure and details used by the

Pennsylvania Department of Highways in the widening and elevating of curves, you are referred to the Department standard instruction sheets C-10 and C-11, one to four, inclusive. As these standards are changing from time to time, the latest issue may be secured by making request direct to the Secretary of Highways at Harrisburg.

It is common practice among field engineers to lay out curves in the same direction with a short tangent, say less than 200 feet between the adjacent point of tangent and point of curve. This produces a broken-backed effect in the alignment, which is not only displeasing to the eye, but is considered poor engineering practice on highways for motor traffic. On a circular curve properly superelevated, the steering wheel of a motor vehicle is held nearly in one position, and if there be a short tangent followed by another curve in the same direction it necessitates quick shifts and turning of the steering-wheel at both the point of tangent and point of curve. These changes of direction are often awkward to make, and thus lead to accidents. Unless a short tangent is absolutely necessary, on account of the location being fixed by points of control, it is generally possible to make adjustments either to lengthen the tangent a reasonable amount, or to eliminate the tangent by compounding the curves. It is desirable that the tangents between reverse curves, after allowing for easements or spirals, should not be less than 50 feet in length in order to permit vehicles to regain equilibrium and run smoothly from the curve superelevated in one direction to the adjacent curve superelevated in the reverse direction. It is much better to have the intervening tangent between spiral points of reverse curves longer than 50 feet, but the topography in many sections of Pennsylvania often makes it advisable to accept this limit.

In this day and age, when important highways must be kept open for traffic throughout the year, the item of snow removal has become an important one. We have found it advisable and possible in many instances to relocate certain sections of our state highways in order to gain the advantage of locations where there is little tendency for snow to drift. All other conditions being equal, hillsides and slopes with a southerly exposure are preferable to northern exposures for highway locations, as they are easier to keep open and free from snow and ice during the winter season.

Soil and drainage features are, of course, of the greatest importance. In the southwestern section of Pennsylvania, where slips and

landslides are so common, and so serious, they have a pronounced influence on the selection and adoption of ultimate locations. Any engineer who attempts to locate highways in Allegheny or adjacent counties without giving sufficient study and thought to the slide question is liable to find himself in serious difficulty. The years of experience that the speaker has had in this section of the state prompts him to the adoption of the policy that the best way to treat slides is to keep away from them. In other words, adopt a location that appears to be free from conditions favorable to slides. In many cases our choice of locations is so limited that we can not avoid all the slipping sections. In such cases, of course, we must face the situation and try to handle the slide in such manner that it will cause as little trouble as possible.

The Pennsylvania state highway system was established by an act of legislature during the 1911 session. Each state highway route was given a number and described, naming the termini and certain intermediate points. In the original act the termini were county-seats or, in border counties, the county seat and a point on the state line. The original act and subsequent amendments created a total of 10,273 miles, which have been adopted by the Department as state highways. Amendments passed by the session of the legislature in 1925 add several hundred miles of state highways, which, however, are not to be taken over by this Department as state highways until June 1, 1926.

It may be of interest to mention at this point that of the 10,273 miles of state highways in our present system, the Highway Department, with the approval of the governor, designated 3952 miles of what we consider the most important or main highways as the primary system. The remainder, of 6321 miles, is considered as the secondary system. It is true that some sections of the secondary system are of much importance and may carry more traffic than some portions of our primary system; however, the primary system was laid out with the thought of providing the most direct and desirable routes for through traffic across the state, and between the large centers of population. Practically all of the interstate and national highways traverse our primary system routes. Prominent examples of the primary system are the Lincoln Highway, the William Penn Highway, the National Pike, the Pittsburgh-Erie route via Butler, the Roosevelt Highway, and the Susquehanna Trail. The efforts of the Department

during the present and preceeding gubernatorial administrations have been especially directed to the improvement of the primary system. Out of a total of 3952 miles, at present all but approximately 300 miles have been improved with some type of hard-surface pavement, and of this 300 miles, some 100 miles are classed as gravel, flint, shale, or stoned road. It is anticipated that the paving of the entire primary system with hard-surface pavement will be practically completed by December 31, 1926. Of the 6321 miles in the secondary system, 3041 miles are improved with hard-surface pavement, and 326 additional miles are classed as gravel, flint, shale, or stoned roads.

As the act under which the Pennsylvania Department of Highways operates specifies the termini and certain intermediate points on each numbered route, we are naturally somewhat limited in making relocations and selecting the ultimate locations for the routes.

The legal authorities to which we have access have advised this Department, in effect, that it is the duty and responsibility of the Secretary of Highways to improve the state highway routes between the named termini over such a location—that is, by such alignment and grades—as will in his judgment give the best results from the points of view of "safety or convenience; of improving grades, and of saving expense to the state in construction and maintenance." He is advised that his duty and power to establish new alignment extend even to the by-passing of intermediate points of control named in the legislative acts, provided that such named points shall be accommodated with a state-maintained spur or connection to the by-passing route.

Before deciding upon the improvement or adopting the ultimate location of any section of highway, we first take into consideration the present and possible future importance of the highway in question. If it be of state-wide importance, such as one of our primary system highways, the ultimate location should be considered from a broad-gage standpoint and should be decided upon only after we are satisfied that the section in question will fit in with the balance of the route across the state. If it be a section of highway of less importance, such as one of our secondary state highways, it should be considered from the standpoint of desirability and convenience of the county in which it is located; or, if the important termini lie in adjoining counties, it should be considered between these limits. If it be a road of importance to only a township or small section of the county, naturally the

ultimate location should be adopted that will best meet the present and anticipated requirements of that particular community. We should always bear in mind that the highways are to serve the public and that economic road operation is the goal of all highway engineers. A highway that is to serve state-wide and national travel should be designed and located with that end in view, and the wishes of the individual must be wholly subordinated to the public welfare. Inferior alignment and grades should not be adopted on such a highway to accommodate sparsely settled sections and small communities. If the road be of only local importance it should be located and designed to suit the communities it is proposed to serve, and also with a view to fitting into other local improvements which may be anticipated in that vicinity in the near future. It often happens that highways which are of comparatively little importance at the time they are located and improved, later become important thoroughfares as that particular section and surrounding sections are later developed because of natural resources or as industrial centers. Much faulty location and future expense can be saved if these matters are taken into consideration before permanent improvement is made. A comprehensive traffic survey was made on the state highways of this commonwealth by the Pennsylvania Department of Highways in conjunction with the Federal Department during 1924. The results of this survey are of inestimable value and are referred to constantly in studying and determining the ultimate location for our highways. After we are satisfied that the route as a whole connecting the termini and intermediate points specified in the highway act is the most direct and economical location, we then are in position to divide the route into the several sections between the termini and intermediate points mentioned in the act, and consider each or any of these particular sections as a unit, redividing into as many shorter sections as may be deemed advisable for thorough study. Where there are two or more possible locations on any section limited between control points, a comparison is made of the length, curvature, grades, soil, and drainage features; communities, or number of residents directly affected; present and anticipated traffic; railroad or street-car grade crossings, intersecting public highways; opinion of local communities and local units of government; damages; scenic considerations; and cost of construction, maintenance, and operation. These data are tabulated on a Department form for convenient study and reference.

Such an analysis, if thoroughly and carefully prepared, forms the basis for the highway engineer to make an intelligent decision as to the best location.

In 1921 the following addition to the powers and duties of the Secretary of Highways was made:

"The State Highway Commissioner shall also have power, with the approval of the Governer, to establish the width and lines of any State Highway before or after the construction, reconstruction, or improvement of the same, not, however, exceeding the maximum width fixed by law for public roads. Whenever the State Highway Commissioner shall establish the width and lines of any such State Highway, he shall cause a description and plan thereof to be made, showing the center line, of said highway and the established width thereof, and shall attach thereto his acknowledgment. Thereupon such description, plan, and acknowledgment shall be recorded in the office of the recorder of deeds of the proper county, in a separate book kept for such purposes, which shall be furnished to the recorder of deeds by the county commissioners at the expense of the county.

No owner or occupier of lands, buildings, or improvements shall erect any building or make any improvements within the limits of any State Highway the width and lines of which have been established and recorded as provided in this section, and, if any such erection or improvement shall be made, no allowance shall be had therefor by the assessment of damages."

This Department during the past three years has been making a special study of the widths of state highway right of way which we consider are justified to meet the immediate needs and the possible future developments. A tentative plan of the state has been made and the width of the right of way of the various routes has been indicated thereon. Surveys are being made and drawings filed in accordance with the law as rapidly as possible, but, on account of the magnitude of the work and the details and accuracy involved, it will require considerable time to complete this work.

Our experience and investigations have led us to decide that the minimum width of right of way on state highways shall be 60 feet. This width will be used mostly on the less important or secondary-system highways. The more important secondary highways, as well as the less important primary highways, will probably have an 80-foot right-of-way. More important primary highways will carry a right of way of 100 feet, and the sections of primary system adjacent to the large cities, such as Philadelphia and Pittsburgh, will probably be the maximum permitted by law, namely, 120 feet in width.

It is generally desirable that the paved section of a highway and other improvements be symmetrical with regard to the center-line, and that the center-line of the improvement be coincident with the center-line of the right of way. There will be cases, of course, where this condition will be neither practical nor desirable, such as sections where the highway is adjacent to a railroad or river, and where there may be buildings and foot-walk on only one side.

The speaker during his experience as a highway engineer has laid out and directed the construction of some hundreds of miles of highways, revising the alignment and making relocations, which seemed at that time quite radical departures from the original location. As he now looks back upon the many relocations and revisions, he does not call to mind a single one that now appears to have been unjustified or too radical. On the other hand, in traveling over the system of highways which he has had a hand in improving he many times wishes for another opportunity to make the relocations that were overlooked or thought too radical at the time of construction. The experience of the speaker in this respect is probably quite similar to that of other highway engineers.

The question then arises, how are we to meet the situation, and secure the best locations available, and locations that will not require extensive alterations in the future? Such an end may be accomplished only by careful and thorough study and investigations, and by the close co-operation of the various departments or parties in any way responsible for the selection of the locations. Surveys should be started in sufficient time to permit of thorough studies and investigations, and not necessitate the rush decisions which have been so common in the past.

It will be necessary to adhere closely to the modern engineering principles so important in highway location to meet the present and anticipated demands of the traveling public. Each project that is to be considered for improvement or ultimate location should be viewed as a single unit, and also with regard to its relationship to the other highways in that locality and the highway system in general. Having available a traffic census, and knowing the present population and territory to be served, the highway engineer is in a position to estimate quite accurately the amount and character of traffic that will use the highway as soon as it is improved. This, however, is not sufficient,

and the engineer should make an earnest attempt to calculate and anticipate the traffic that may reasonably be expected to develop during the next decade or two. After collecting traffic data a few more years we will be in much better position to forecast and predict traffic growth, but the paucity of such data at present does not justify overlooking or neglecting the making of a reasonable attempt to predict future traffic.

Summing up then, the speaker feels that we should not waste our time criticizing the faults and errors of our predecessors, nor should we spend valuable time worrying about the errors of commission, and omission especially, which we have made; but we should make an earnest effort to profit by these errors, and, by study and co-operation, establish our highways on the most economic locations that it is possible to secure.

DISCUSSION

Samuel Eckels:* The general principles presented in Mr. Jackson's thoughtful paper on this important and rather elusive subject of road location are indeed very sound. It is so much more difficult to discuss the principles of road location in general than to discuss a definite road location project that one can not fail to admire the way that Mr. Jackson has presented the subject.

The importance of the subject is neatly stressed in Mr. Jackson's statement that the location of the highway, if properly worked out, is really the only permanent part of the highway structure. Pavement, subbase, drainage and other elements are subject to deterioration and replacement. Permanent locations are important not only because of the cost involved in the highway itself, but also because of the investments and developments that take place as a result of the highway, which are in most cases predicated upon the assumption that the highway is to be a permanent artery of traffic.

Mr. Jackson quite properly emphasizes the fact that safety of the highway to the traveling public is the most important consideration. It supersedes directness or service. We in Allegheny County who are struggling with the elimination of grade crossings, abolishing dangerous curves, widening narrow roads, erecting safety barriers, removing

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and preventing slides, and in the maintenance, through the legal department settling personal damage claims, know only too well the importance of safety as a prime requisite in highway location.

I believe the element of directness is more important in state highways, where objectives are often long distances apart, than it is in county highways. Without being selfish, we must realize that county highways are primarily built for the service of the people in the county. They are paid for by the people in the county, so that in locating our county highways we must divide our efforts between serving existing communities more advantageously, and locating new roads which will tend to develop new communities and new areas of population.

In the early history of our country, roads were located connecting centers of population and industry, railroads having taken up most of the available low-level roads before modern highways came into their own. The tendency of population was to centralize at important shipping or transportation points and highways were considered of minor importance. The invention of the automobile brought about very radical changes in highway location, which immediately led to an evolution in the construction of highways. The first roads constructed were primarily dirt, and these later were macadamized, and I recall very distinctly the former methods of placing macadam on the old National Highway, the rock being delivered along the line of the work, stored in piles and broken up with a comparatively light hammer. Care was taken in placing the macadam or broken stone on the road that the dust had been carefully removed. Later the Telford macadam came into use and the rubber-tired buggy and light wagon were then seen on the road; bicycles also used these roads to a considerable extent. Then followed what is known as a hard-metal surfaced road. Brick with cinder, gravel, and dirt base came into general use, then the concrete base with an asphalt top, and the latest development is an all-concrete road.

As the automobile became more popular and the speed greater, there was an increased demand for more and better improved roads. Bridges which were located without any particular attention being paid to alignment, sharp curves and grades became very dangerous to traffic. The number of automobiles increased from a few thousand in 1905 to about twenty million in 1925. The low-speed vehicle

became a continuous source of annoyance to the rapidly traveling, motor-propelled vehicle.

The development of the automobile into trucks, moving vans and commercial freight trucks, and now the high-speed motor buses, has led to a more intensive study of the location of highways. It has become necessary to eliminate many dangerous curves, relocate bridges, superelevate, widen and "daylight" curves with short radii. Many roads have had to be straightened out and widened to take care of this increase in traffic, and careful study of many of our roads throughout Western Pennsylvania leads one to believe that a great many of them were located on the paths formerly traveled by cattle when being taken from one locality to another. This seems to be true in a great many towns in our own vicinity.

You have heard Mr. Jackson state how they have saved considerable mileage by the straightening out of roads. Allegheny County is now doing the same thing, and a concrete example of what can be done in the location of a road is that of the Evergreen Road, between Keown Station and Stitzer's Corners. This road was formerly constructed on the side of a hill and in the four miles which is now being reconstructed there were at least thirty very dangerous curves. The road as now laid out between the two points mentioned above is 3½ miles long and does not have a dangerous curve throughout the entire length.

The heavy traffic imposed upon our roads and the requirements for additional width are very evident to one using our modern highways. Motor buses and trucks may now, according to law, have an overall width of 96 inches, from which you can readily see that it is practically impossible for two such trucks or motor buses traveling at a high rate of speed to pass on a 16-foot road. Over the Turtle Creek bridge, but recently opened to traffic, four loads were observed crossing this bridge having a gross weight of 35 tons each.

The construction of the hard-metal road during recent years has probably been given more attention than any other phase of civil engineering now being practised in this country. Engineers are practically a unit on a majority of the specifications for road work, and it seems that the following should be given very careful attention by civil engineers within the very near future:

1. Study leading to the development and design of what might be properly classified as a permanent road material.

2. Universal adoption of standard specifications, and, as far as possible, standards of construction.

3. More intensive study of traffic conditions and development.

4. Encouragement of the adoption of a standard system of road marking and safety signals.

5. Elimination of grade crossings and grade separations at intersections.

6. Further study leading to and the encouragement of the decentralization of population and industries.

When the present Commissioners of Allegheny County took office on January 1, 1924, Norman F. Brown, a member of this Society, was appointed Director of the Department of Public Works, it being the intention of the Commissioners to have him co-ordinate all the engineering activities of the county under one head. The appointment was made by the Commissioners because they deemed it advisable to have this work done under the supervision of a competent engineer, and for the further reason that Allegheny County annually expends more money than some states on its roads and bridges.

The condition of the contracts for the construction of bridges in Allegheny County shows the result of the far-sightedness of our Commissioners.

The Road Engineering Bureau of the county was reorganized and instructions were given by Mr. Brown to develop a comprehensive highway system. Previous studies had been made and volumes of information were available. The map of the county was brought up to date, showing all the improved roads in the county, and the relative importance of each section of the county was given intensive consideration. Engineers, manufacturers, industrial interests, public utility companies, boards of trade and all parties who had an interest in our county were consulted on this project. After a study covering a period of approximately nine months a plan was developed, later called the Allegheny County Major Highway Plan. This plan provides for radial lines leading from Pittsburgh—the heart of the county—to the outlying districts and to important cities in surrounding counties. Two major loops entirely encircling Pittsburgh have been incorporated in this plan, and when the plan is fully developed it will be

possible to by-pass the city of Pittsburgh when it is approached from any direction.

Allegheny County now has under construction the Lebanon Church Road, leading from the Miller's Grove and Clairton Road, in Baldwin Township, to the Pittsburgh and McKeesport Boulevard, just west of Dravosburg. This road is four miles in length, and when completed in the fall of 1926 it will be possible for one approaching Allegheny County from the west or the northwest to travel from Sewickley around Pittsburgh on the west and on the south to McKeesport without approaching Pittsburgh within a less distance than four miles. This road is entirely on the inner belt.

During the early season of 1927 we expect to have completed the northern half of this inner belt, and, if one desires, using the same starting point at Sewickley, he can travel to Oakmont on an improved highway under the same conditions as on the south, the distance from Pittsburgh being about the same. On the east and west of the county the inner and outer belts are coincident one with the other, this being necessary on account of the peculiar topography of Allegheny County, which is probably more rugged than any other equal area in Pennsylvania.

The Commissioners of Allegheny County have recently agreed that no highway shall be constructed of a width of less than 18 feet. They have approved the adoption of the principle of elimination of dangerous curves and grade crossings, steep grades, the protection of the traveling public by means of the installation of hundreds of thousands of feet of protective barrier, and the installation of hundreds of danger signals.

N. F. Brown:* Referring to the map showing Allegheny County's major highway system, I hope all the engineers in this organization will become familiar with it, as we had a great deal of trouble getting these lines established and adopted.

We have certain difficulties in building and maintaining roads in Allegheny County which probably the State Highway Commission does not encounter. I would like to say first that we have in this county five asphalt plants, so as to enable us economically to maintain our large mileage of asphalt roads, which probably the State Highway

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Department with its greater territory could not do as advantageously as we can. They may find other types of construction more advantageous in the center of the state or the northern or southern part than it would be in Allegheny County or in the extreme eastern part of the state.

We have difficulty at times in deciding upon the type of pavement to adopt on new roads. Mr. Eckels mentioned the Lebanon Church Road, which is but one of the fifteen or twenty miles of new road which we are building. We are trying to determine the type of road that is almost maintenance proof—a type of road that will outlast the life of its bonds, which is usually 30 years in this county. Reinforced concrete roads require a certain amount of maintenance after the second year; the same holds true of asphalt roads. We have adopted in some places a brick road. We are open minded and considering various types of road.

We are also considering the width of road that is necessary for the traffic. Mr. Jackson brought out the fact that in some places we have 16-foot and 18-foot roads; there are some places in crowded districts where we need a greater width.

I would like to ask Mr. Jackson or the Highway Commission what factors determine the exact width and type of a road in which Allegheny County pays a large proportion of the cost. In some cases we pay property damages; in others, we pay one-half the cost. How do they determine these two items?

S. W. Jackson: Mr. Brown, I judge, is principally interested in the roads on which the county pays a portion of the cost. In the first place, the attitude of the state in determining the width of the pavement is not a selfish one. In proof of this, the pavements on the primary system where the state ordinarily pays 100 per cent. of the cost are 18 feet in width. The 16-foot width is used principally on state-aid roads, where the state pays not over 50 per cent. of the cost, and on secondary state highways, where the counties and townships often pay a portion of the cost.

In the early days of our road building the pavements were principally 14 and 16 feet. Sixteen feet was considered ample for any country pavement until motor trucks began to use the highways extensively. In most of the counties of the state the local officials are not

willing to contribute toward the construction of country highway pavements more than 16 feet in width. There is such a large percentage of country roads without any improvement that the sentiment is for greater mileage of improved surfaces and not so much stress is placed on a width over 16 feet in a majority of the country sections.

Since the law now permits the operation of motor vehicles up to eight feet in width, I think the State Department of Highways is pretty well convinced that a 16-foot pavement is not adequate near large centers of population, and on roads where the traffic is comparatively dense. The district engineers of the Department of Highways, in recommending projects for improvement to the central office, report the present traffic and the estimated traffic in 5 and 10 years, and the width determined is based largely upon these figures. At the request of Mr. Brown's department, several of the state-aid projects in Allegheny County, where the traffic apparently will be dense, have recently been designated for pavements 18 feet in width instead of 16. The state has a fixed amount to spend in each county on a 50-50 basis, and naturally a shorter mileage of 18-foot pavements will be constructed than had the same amount been expended for 16-foot pavements.

As to the type of road, the district engineer in each case is supposed to make an estimate upon more than one type if there seems to be a possibility of securing close competition between different types. In many cases we find that we can not construct a brick, asphaltic concrete, or asphalt surface with concrete base, as such types can not compete with the one-course concrete road; consequently, a large percentage of our pavements are concrete. If there were cases where brick or asphaltic concrete pavements could be built as economically as concrete we would not hesitate to use them.

N. F. Brown: If you had to take care of all the maintenance for the entire life of the 30-year bonds, have you any particular specifications you would yourself adopt as worthy of recommendation that would relieve the pocket-book that is paying the bills; that would reduce constant maintenance expenditures?

S. W. Jackson: I think you solved that question in Allegheny County. Your roads are close together and you can locate four or five asphalt plants in the county, and maintain your roads economically.

We could not follow such a procedure in the state. Our roads are so scattered that we would have to install so many asphalt plants that it would be too expensive, nor would a few plants with extra long hauls prove economical. On that account concrete is more economical for us to maintain. A local crew with a small supply of cement and aggregates and a small mixer can repair concrete pavements economically.

N. F. Brown: Does that apply to brick as well as to asphalt?

S. W. Jackson: Yes, I think so. Two-course material, like asphalt or brick, is ordinarily more expensive than concrete.

N. F. Brown: How about maintenance?

S. W. Jackson: I would not say there is much maintenance on the brick and concrete road. For the first few years the repairs are ordinarily only sealing cracks, except where they break at the corners. The first concrete pavements we built were seven inches in the center and five inches on the sides, and the sides were too weak. A great many corners were broken down. We now specify 7 to 8½ inches on the sides and 5 to 6½ inches in the center, and the heavier sides ordinarily withstand the traffic.

N. F. Brown: Did you ever build an eight-inch concrete base throughout with brick on it?

S. W. Jackson: I do not recall ever building on that design.

N. F. Brown: Would you have much maintenance on such a type of road?

S. W. Jackson: No, but it would mean more first cost on the base.

N. F. Brown: What is your opinion of a road with an eight-inch concrete base with a four-inch brick pavement from the viewpoint of permanent construction and reduced maintenance charges?

S. W. Jackson: I would first make an estimate on other types to compare with such a design.

N. F. Brown: I am thinking more of maintenance costs than first costs. You can spend a good deal more for maintenance in 30 years than the original cost and six or nine thousand dollars more additional first cost per mile does not mean much if you can eliminate the constant maintenance charges. That is the point.

S. W. Jackson: Your maintenance charges would be about the same on either type, asphaltic concrete or brick surface, with extra-heavy base. I think that has been worked out.

N. F. Brown: Where have you brick roads of that type?

S. W. Jackson: We do not have any of that type on state roads. We have a good many brick roads on five-inch and six-inch base; we do not have any on eight-inch base.

N. F. Brown: Don't you think the present road with five-inch concrete base has passed out of existence?

S. W. Jackson: I think that the five-inch base of lean mixture is entirely inadequate for our present traffic.

N. F. Brown: Do you maintain any paving on highway bridges?

S. W. Jackson: Yes.

N. F. Brown: Do you recommend concrete paving on bridges?

S. W. Jackson: We have comparatively few large bridges. Most bridges of any size are built by the counties. But we put reinforced concrete floors on concrete structures and on steel trusses and we have had some with block flooring. Most of our bridges are short-span bridges—not truss bridges.

N. F. Brown: We have wood block and brick. What type is the most advantageous to use on bridges for both maintenance and actual wear of the material itself? I am interested in hearing what your experience has been.

S. W. Jackson: I feel there is a man present much better qualified to speak on that subject. Mr. Covell has had a great deal more experience on bridge work. As I say, our bridge work is on limited spans, mostly 40 to 50 feet.

V. R. Covell, *Chairman*:* The viaduct near Ligonier was built and is maintained by the state?

S. W. Jackson: Yes.

V. R. Covell: What is the type of floor?

S. W. Jackson: That structure has a concrete floor.

V. R. Covell: It has not been down long enough to tell what the result will be?

S. W. Jackson: No, it was put down during the past year.

N. F. Brown: A gentleman back here wishes to know if you favor gravel for a concrete road?

S. W. Jackson: In a few sections of the state we have gravel that is excellent material, but in this section of the state some of the gravel is very good quality and some is not so good, and on that account we have not accepted gravel for concrete work except in a few cases.

N. F. Brown: That was not my question, but I would like to inquire if you find that the eastern gravel is better than western gravel, and, if so, why?

S. W. Jackson: I have had some experience with gravel in the northern central part of the state, and there is some gravel in that section that is of excellent quality. It is glacial deposit, trap rock, granite, and hard limestone, and it is very durable. The material found here in the rivers is mostly sandstone. Some is very good, but quite a portion is soft material.

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N. F. Brown: Is that northern gravel as good as the Delaware gravel?

S. W. Jackson: I am not familiar with the Delaware gravel. We use Monongahela, Allegheny, and Ohio river gravel and sand in our concrete structures and pavement bases, but on the wearing surfaces its use is questionable.

N. F. Brown: Are you not almost compelled to use gravel in the central part of the state?

S. W. Jackson: No, not for the pavement surfaces. We use large quantities for concrete bases, etc.

J. P. Leaf:* I came here to listen to the paper and I have been very well repaid for it. We all take off our hats to the Department of State Highways for the excellent roads they are building and the immense amount of roads they are building. As a general proposition, the state highways of Pennsylvania beat any other state so far.

On the matter of the width of the road, Beaver County, that I represent as County Commissioner, is something like Allegheny County in topography. But we think a long road is better than a wide road; we ought to get them long before we get them wide. You can build a 16-foot road in our little county without excessive side cuts. You would think you could build an 18-foot road for just the proportionate increase in cost, but when you come to make your estimates and go into side-hill cuts and fills, the cost of that extra two feet is away out of proportion to the original cost.

I was very much interested in a plan Allegheny County is adopting. In meeting with the road commissioners and the Planning Commission we have agreed to meet the roads as Allegheny County builds them in those places where they join Beaver County. We are now building three or four miles of the Beaver and Pittsburgh road on this back line, and when Allegheny County gets down to our line we will build three or four more miles and we will have a back road in Beaver County on the north side of the Ohio River to Pittsburgh.

*City Engineer and Consulting Engineer, Rochester, Pa.

We have been putting on a pretty strenuous campaign in Beaver County in the last three years. We thought when we got our bond issue started it meant a fifty-fifty proposition with the state. The state was so poor it could not accomplish that, and we had to build our roads at county expense; but, in checking up, we find that the state has built a good deal of road in our county that is 100 per cent. state road, so, as it stands, we are spending about $1,500,000 in Beaver County and the state is spending about $1,200,000. They are not always the roads we would build, but they are in Beaver County and we are giving the state credit for every road it builds for us.

This matter of eliminating grade crossings is something like war propaganda. We have had the idea that the grade crossing is a menace. It does not hold a candle to the improved roads between certain towns. We have a road between Brighton and Rochester with not a person living on it and there is no cross-road. It is perfectly straight, and yet there were eight or nine people killed on it. They run down from Brighton straight into a stone wall. On a straight highway that beats grade crossings all to pieces. We have one of the worst grade crossings in the state of Pennsylvania, New York Street. Unreasonable as it seems to be, there was never a person killed on that crossing. There have been several injured, but there was never a person killed. We are going to eliminate it. We have only 26 crossings in Beaver County. The state gives us about $50,000 for each one.

I have always advocated gravel aggregate where you could get good gravel, and we have some very satisfactory roads using gravel; but, of course, you must use gravel that is all hard material. The towns are building roads with a good deal of gravel because the roads are wide, and it is much cheaper to build concrete with gravel than with stone in our district.

I think all road builders are making a mistake, as Mr. Jackson stated, allowing weights equaling railroad trains to go on the surface of roads. It is not possible for any material we use to carry 13 tons. When a 13-ton truck puts on a one-inch chain and starts on a wet surface you might as well go on the road with a sledge hammer. I believe the truck man who is using the road would be just as far along if we would make every vehicle on the public highway use pneumatic tires. They have found them more economical on four- or five-ton trucks, and it is certainly easier on the road. When a truck

uses hard vulcanized rubber tires it is pretty nearly as hard as iron, and when the truck has cut out a piece of the tire you might just as well use a hammer on the surface of the road. It is as bad as horses' feet used to be. If it is necessary to use a heavy truck occasionally, use it at low speed, and it will not hurt the ordinary road. If you take 13 tons and go 15 miles an hour with it, it is a good deal more dangerous than to go across a railroad crossing, because there isn't any brake that will stop that truck in a reasonable distance if a child runs across the road or something darts out of a side street. Most of our fatalities in Beaver County come from trucks. It is not always the fault of the truck driver. When we have three methods of transportation, all good—railroads, roads, and rivers—we should let each one of them carry its own stuff. You all have to pay the freight on the railroads and the public highways, and you might as well let the street railways carry what they can and the paved streets what they can, and not attempt to take away from the rails what they ought to carry.

V. R. Covell, *Chairman*: You may not all know Major Leaf. He is not only an engineer, but a county commissioner of Beaver County.

May I ask what is being done along the line of limiting loads?

S. W. Jackson: This would be a rather dangerous subject to bring up in the legislature. It is like the traction-engine law. They are afraid to discuss it. There is always considerable talk about reducing the maximum load limit, but, like controlling the weather, little has been done about it. If it is ever started, it will have to be in the voting districts where the representatives are elected.

N. F. Brown: Mr. Eckels spoke of the 35-ton truck on the Turtle Creek bridge. I never heard of a 35-ton truck.

Samuel Eckels: The gross weight of truck and load was 35 tons.

J. P. Leaf: I knew of a case where a truck had on 15 tons of steel and the truck weighed seven tons, and the sign on the bridge

said eight tons was the maximum load. The truck went through the bridge.

S. W. Jackson: We had a county bridge in Westmoreland County with a sign that for years had limited loads to four tons. It was of 125-foot span and 25 feet above the creek bed. Last fall, one of the contractors loaded a heavy steam-shovel, weighing 25 or 30 tons, on a special truck and had two five-ton trucks hauling it and a five-ton truck to hold it back, and they did not hesitate to go right across this bridge, although it settled several inches. The funny thing about it was that one of the neighbors happened to see it and ran out quite excited when he saw a flivver runabout coming toward the bridge. He waved it back, saying the bridge was not safe. The driver said if those trucks got over the bridge safely he would take a chance.

Samuel Eckels: Some of the new life that was put into the Department of Allegheny County could not understand why the state adopted the policy of a 16-foot road, and we immediately proceeded to try to find out why and wherefore. Recently we made a trip to Harrisburg and talked the matter over with the acting Secretary, and within the last month we have received from the State Highway Department of Pennsylvania an agreement whereby the state, under state aid and state bond aid funds, has agreed to pay 50 per cent. of the cost of 18-foot roadways in Allegheny County; and all those roads happen to be in these two belt lines.

The purpose of these belt lines is not primarily to lead you away from Pittsburgh. There is an immense amount of traffic in Allegheny County; the tonnage is probably heavier than the tonnage of any other city in the United States, and that heavy traffic occasionally wants to go through the city of Pittsburgh and compete with the lighter and faster traffic which is met in there, and the heavy congestion. Tourists quite often do not wish to go into a large city; and in going east and west or north and south it is probably the means of saving from half an hour to three hours in going through Allegheny County. There are a great many by-passes. Coming from the west over the Steubenville Pike and then turning directly to the south and the southeast and coming out at the extreme southeast corner of the county and joining the Lincoln Highway, anybody making that short

distance of 20 miles can save not less than two hours. There are other routes you can take whereby you can save three hours.

The radial lines are not indicated on there as they will be on other maps. For instance, we have two distinct routes traveling along either bank of the Ohio River. We have a route on the south side of the Monongahela River. There will be another route known as the Boulevard of the Allies all the way through Allegheny County to Monongahela City, practically all of which is completed. It only needs a connecting street in the city and a short new connection in outlying boroughs. On the Allegheny River we have the Freeport Road. If you want to go to Butler, you go right straight north. The Perry Highway runs almost directly north. To the south there are innumerable radial lines. If you want to travel to Washington, Pa., at the end of this year, I can pick out five distinct routes for you. In regard to radial lines being neglected, I do not think the contention is borne out in any way. Some of our radial roads are not in very good repair, but out of 210 miles that were absolutely gone in 1924, 50 miles were reconstructed and repaired in 1924, 70 miles were reconstructed in 1925, and 60 miles will be reconstructed and resurfaced this year; and 60 miles in 1927 will finish the original program, including other roads added to the list.

WINTERS HAYDOCK:* I wish to call your attention again to what Mr. Jackson has said in regard to the policy of the Department of Highways of Pennsylvania as to the widths of right of way for highways. I wish to emphasize the importance of this phase of highway development. The time is sure to come when we will realize that on main trunk highways, especially in the vicinity of the larger towns, there should be sufficient width of roadway to permit of two lanes of moving vehicles in each direction. The full efficiency of the highway as a traffic carrier can be secured only by an arrangement which permits the free movement of all vehicles at various rates of speed. There must be a constant passing of the slower vehicles by the faster vehicles. This passing can not be done in safety in heavy traffic where there is width for but one lane of movement in each direction. The efficiency and safety of the highway and the convenience of its users are materially injured under such conditions.

*Chief Engineer, Transit Commission, Pittsburgh

Furthermore, I think we shall come to realize the desirability of having sufficient width of berm, wherever possible, to permit vehicles to stop beside the highway without obstructing traffic. This is especially true where the highway passes through small roadside villages or groups of farm buildings. The question of pedestrian ways is also important, particularly within these villages. Such roadside villages may spring up in the future at unexpected places. The ideal main trunk highway will therefore have sufficient right of way to permit, as required, provision for two lines of moving vehicles in each direction, space for stationary vehicles outside of the traveled portion of the road, and satisfactory pedestrian ways.

The present impossibility of attaining such an ideal, due to financial limitations, is not necessarily of a permanent nature, and, as it always becomes more difficult to secure desired right of way as time advances, it would be a commendably far-sighted policy to secure in the beginning as much as possible of the right of way necessary for the width of highway which in future will become desirable. In passing, it may be mentioned that in many states the public has accepted without complaint the standard right-of-way width of 100 feet for all railroads, and that whenever a new railroad is built the community does not object to this amount of land being taken; yet in these same communities the acquisition of adequate right of way for highway purposes is frequently obstructed. Obviously the American public, and the engineering profession also, are much in need of education as to the country's future highway requirements.

S. W. Jackson: I think this belt-line system they are adopting in Allegheny County is one of the most advanced steps that has been taken in a long time. There are dozens of radial routes from Pittsburgh to the county line, but the cross connections have not been very satisfactory. With the completion of this lay-out of belt lines it will be possible to cut across from one radial line to another and I think it will meet what has been a crying need of this county. The county has been pretty well supplied with radial lines, but, as this other gentleman has brought out, the conditions on the radial lines, especially near Pittsburgh, should be improved. Some of those objectionable conditions are on our state highways. That is a problem we shall have to solve in the near future and straighten out those kinks and

narrow places. It can be done more economically now than in a few years, on account of the rapidity of growth and the increase in property values.

P. W. PRICE:* The width of right of way that was spoken of does not include slopes. Our old system of 33 feet and slopes will in many cases give more width of usable roadway than will be secured by adopting a width of 60 feet without the right to construct slopes in addition to this width.

It would seem to me preferable to continue the old method by which the slopes could be taken in addition to the width fixed by law for the roadbed itself. In this way there could be no question as to the ownership of land bordering on a public highway. The only restriction placed on the adjoining property might then be a set-back line which would prevent buildings being erected too close to the road, especially on curves and at road intersections. In this way, if the character of a district changed from rural to a fully developed business district, the main street through the community, which was formerly a country road, would then be assured of a total width equal to the distance between the old set-back lines, so that this provision for future development would result in a gradual change from a state highway 60 feet wide, and with set-back lines giving a total width clear of buildings of 80 to 120 feet, to a business street of an equal total width. Would not something like this be well worth planning for at the present time when these new rights of way are being established?

S. W. JACKSON: Where we make slopes outside of the 60-foot or 120-foot right of way, they will be taken in special cases as easements. The state or county will not purchase the slope width outright, but simply procure the right to grade and maintain the slopes. The property owner will own the property, but he can not use it in any way detrimental to the road.

THOMAS FITZGERALD:† As a street-car man I was particularly interested in the statement with reference to taking heavy freight off

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the highways and putting it on the rails where it belongs. That is particularly attractive to me. The Pittsburgh Railways operates two interurban lines, one from Pittsburgh to Washington and one to Charleroi. We have established a pick-up and delivery system on the Washington line and the result has been encouraging. In the last six months we have hauled 70 to 80 per cent. more freight over the line from here to Washington than we did just prior thereto. Washington is in a depression just at present, and an increase of that amount means that we must have taken considerable truck traffic off the highways. Charleroi and Monongahela, which we also serve, offer a better opportunity. Co-ordination of rails with rubber-tired vehicles offers the great opportunity for all rail carriers to help in the solution of this problem.

I was also particularly interested in the remarks regarding hard rubber tires. I don't believe a road can be built that will stand up under a 15-ton to 30-ton truck with hard rubber tires. In this connection, I would like you to remember that the public utility companies are taxed to maintain competition against themselves.

It seems to me the high character and ability of the men who are applying their minds to this problem have been very evident here to-night. The citizens of this county and of Pennsylvania are to be congratulated on the very excellent work that is being done on this problem. Take, for instance, those by-pass routes. In this it appears that the county is following the lead of the Pennsylvania Railroad and other experienced transportation interests in by-passing their heavy traffic around the congested centers. Main highways are also being planned to avoid such points. Those policies would not have been possible under the old political conditions, and it seems to me that these things that have been brought out here to-night show tremendous progress in what is probably the most important factor in the development of our transportation.

INCREASING THE PRODUCTION OF OIL FIELDS*

By R. E. Somers†

In all forms of mining, more or less of the valuable mineral is left in the ground, because under existing economic conditions it has not paid to get it out. Thus the petroleum industry, with pumping as its final method of extraction, has been leaving a part of its product in the sands. This fact has never been seriously doubted, but it has received very little attention in the past, and the estimates of oil actually extracted have varied all the way from 10 to 90 per cent. Within the last few years, however, the prospector has been finding that promising wildcat territory in this country is becoming scarce, and the inefficiency of the present methods has been coming in for more consideration.

It is fundamental in this matter to estimate accurately the amount of oil left underground at the time of abandonment. As yet there are no widespread and detailed figures available, but on the basis of our knowledge of sand porosities, oil production, and a few particular tests, a general estimate is possible, and the astonishing conclusion is reached that in the hard-sand oil fields, such as the Appalachian and Mid-Continent, only 15 to 25 per cent. of the oil is recovered; and under the most favorable conditions in the soft unconsolidated rocks of California, or the Gulf Coast, not over 40 or 50 per cent. For the country as a whole, an average of 30 per cent. might be used, which means that when pumping is the final method of extracting oil 70 per cent. is left in the ground.

On January 1, 1922, a report on the petroleum resources of the United States was submitted by a committee of experts, and it was estimated that at the beginning of the oil industry in 1859 the amount of oil available under technical and operating conditions that went no further than pumping as a means of extraction was 15,000,000,000 barrels. This figure has been slightly modified since that time, so that at present it can be estimated that the original resource was about 16,000,000,000 barrels, of which we have now produced about one-half. But these 16,000,000,000 barrels were only about 30 per cent.

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of all the oil in the ground, and the total amount that really existed as fluid oil was more nearly 53,000,000,000 barrels.

Not even the most optimistic student of oil production, however, would venture to believe that all of these 53,000,000,000 barrels will in time be extracted. We can not even forecast processes so universally efficient that they will under all the varying conditions of oil occurrence get every barrel of oil from the sands. We do look forward, however, to the probability of perhaps doubling our present extraction figure, or of making it at least 50 per cent. instead of 30 per cent. To accomplish this it will be necessary to put into more general practice methods that go beyond pumping as a means of extraction, and to carry out a reasonable development of these methods.

Of the various ways of increasing extraction, there are several which can be considered merely as improvements of ordinary operating technique and practice; for example, production is often impeded by a deposition of wax or paraffin in the sand near a well and around the equipment at the bottom of the well, and removal of this wax may be accomplished by shooting or underreaming, by heating, or by some chemical treatment. Another operating refinement is to use back-pressure on wells so as to conserve the gas pressure, and therefore get the benefit of its expelling effect on the oil over as long a period as possible. Finally, cementing and plugging of wells are being more effectively done, with higher extraction of oil as the ultimate result.

On the other hand, there are methods devised solely for the purpose of getting more oil than can be obtained by pumping. They may be named as follows:

1. Vacuum.
2. Compressed air, or gas.
3. Flooding.
4. Mining by shafts and tunnels.
5. Open-cut mining.

Vacuum. This method was first used in the old Triumph pool in Pennsylvania in 1869. It consists in connecting a vacuum pump to the well and thereby reducing the pressure. There may be a central pump on a lease with suction lines extending to each well, or indi-

vidual pumps may be provided for each well. The effect is a reduction of pressure on the oil in the sand, a consequent release of gas in solution, and an expansion of gas entering the well greater than would otherwise be the case. It is generally used on wells that have declined nearly to atmospheric pressure, so that the actual reduction of pressure is not more than 15 to 20 pounds per square inch.

Where the production is gas to be used for gasoline extraction, the vacuum process gives very beneficial results. The lowered pressure releases from the oil some of the gasoline constituents that are held in solution at the usual greater pressures. These enrich the gas, and a higher and more profitable percentage of gasoline is obtained. Many gas-gasoline plants owe their profitable existence to the vacuum exerted on their wells.

The effect on oil production is, however, open to some question. Every bit of light gasoline that is volatilized by the vacuum makes the remaining oil more viscous and consequently harder to get out of the sand. Hence, although there is at first an increase in oil produced per day, the total or ultimate production of oil from the well is only slightly more than by ordinary pumping methods, and does not balance the increase in expense and operating troubles.

Compressed Air or Gas. One of the most successful and widely used methods is variously known as the compressed air, Smith-Dunn, or Marietta process. It was put into successful practice in 1911 on the Wood farm near Chesterville, Ohio, by Mr. I. L. Dunn, although the idea came from observations made several years earlier.

The principle of this process is to put compressed air or natural gas into a few of the wells on a lease, thereby raising or restoring the pressure in the sand, and forcing more oil into the remaining wells. The pressure tends to go outward in all directions from each air well, and therefore an arrangement to spread it satisfactorily over a lease might be to put the air into a ring of wells about one-half way from the center to the boundaries of the tract. In practice, however, allowances have to be made for the irregular spacing of the old wells, and also for sand irregularities, so that the actual arrangement may not appear very formal.

The air wells are fitted with tubing and packers in such a way that the pressure enters the sand without leakage. See Fig. 1. The

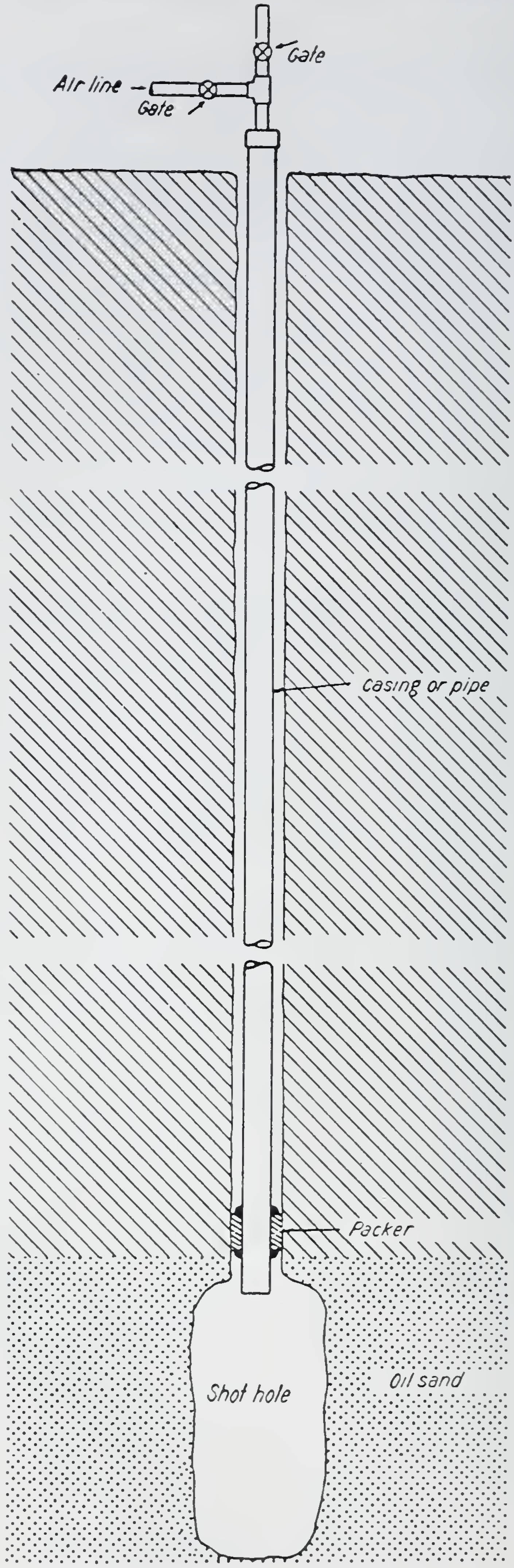

Fig. 1. Shallow Well Equipped to Receive Air Pressure (After J. O. Lewis).

amount of pressure varies between 10 and 300 pounds per square inch. Some sands are loose, with large pore spaces, and a high pressure tends to blow a channel through to the nearest well, through which the air flows without further increasing the yield of oil. In such cases the low pressures are necessary. In other sands the pores are small, no channels are blown, and an increased yield can be obtained only with high pressure. In any case, the proper pressure is determined by experiment.

Air is used at the rate of 10,000 cubic feet of free air a day, on the average, for each well, both air and oil wells included. Looser sands take more air than the tighter sands. A compressor, usually of 75 to 100 horse-power, is centrally located on the lease and supplies the air to each well through two-inch to four-inch mains, and one-inch laterals. Sufficient compressor capacity may also be supplied, in additional units where necessary, to pump the oil wells.

Either air or natural gas may be used. Natural gas is to be preferred, since it comes out of the oil-wells laden with gasoline fractions which it has dissolved under pressure in contact with the oil and which may be extracted in a gasoline plant. On the other hand, this process is usually applied to sands that have declined to the point where there is very little gas to be compressed and returned through the pressure wells. Gas can thus be obtained only through the fortuitous presence of a neighboring gas-sand separate from the oil producer, and hence it is much more common to use air. In its passage through the sand, the air usually mixes with the small quantity of gas remaining there, and later can be used in gas-engines with proper carbureter adjustment. A few exceptions are noted, as for instance at Bradford, Pa., where the air and gas do not mix, probably due to the fineness of the sand, and therefore offer insurmountable obstacles to use in internal-combustion engines. Air is also objectionable in any field that is depending much on profit derived from gasoline extracted from its natural gas, as the air dilutes this gas. No change is made in the oil-wells in this method. They are pumped by the usual methods, or perhaps fitted with compressed-air pumps, which makes for a saving of power costs because of the already established use of compressed air on the lease. No extra oil-wells need be drilled unless some local condition seems to demand it.

The increase of oil production by this method is very definite.

The daily yield of a lease is increased from two to ten times and reaches its peak in from one to four years. Even after that, however, it declines slowly—not rapidly. Very few, if any, properties have proceeded to abandonment under compressed air, but on several the total yield per acre has been increased 100 per cent., with an indefinite future ahead of them. The cost of installation is about $200 to $300 per well.

Flooding. In the Bradford pool of northern Pennsylvania and southwestern New York the yield is increased by letting water into the sand through a few wells of a lease, and creating thereby an expanding or progressing flood. This flood washes along some of the oil previously sticking to the sand grains, and its capture is affected in oil-wells that intercept the flood.

That such a method could be successful was discovered accidentally about forty years ago through pulling the casing in old wells and letting in water from upper sands. In the course of time an increase in daily production was noticed in neighboring wells that had not been pulled and the cause assigned to this accidental flood. Since then flooding has been extended until at the present time it is an outstanding development in oil production. It has not, however, been successfully used elsewhere than in the Bradford group of fields.

In the most advanced practice, the wells that initiate the flood run in a line through the center of the area to be flooded. They are from 125 to 150 feet apart, or, in other words, their spacing is at the rate of two to three wells per acre. The former spacing in the field was one well to four or five acres, and hence in starting a flood it is customary to use old wells, when they are in the line selected, with new wells drilled to make up the proper number per acre. Then a row of oil-wells is located on each side of the line of flood wells, each oil-well being in a staggered position between two flood wells. See Fig. 2. They are likewise spaced from 125 to 150 feet apart and the same distance from the water wells, again utilizing old wells, or drilling new ones as necessary. The flood proceeding from the center-line increases the oil production of the first line in a few months, and brings it to a maximum in perhaps one to three years. Then these wells decrease in oil and increase in water as the flood reaches and passes them. In a similar manner, as the flood spreads, new rows of

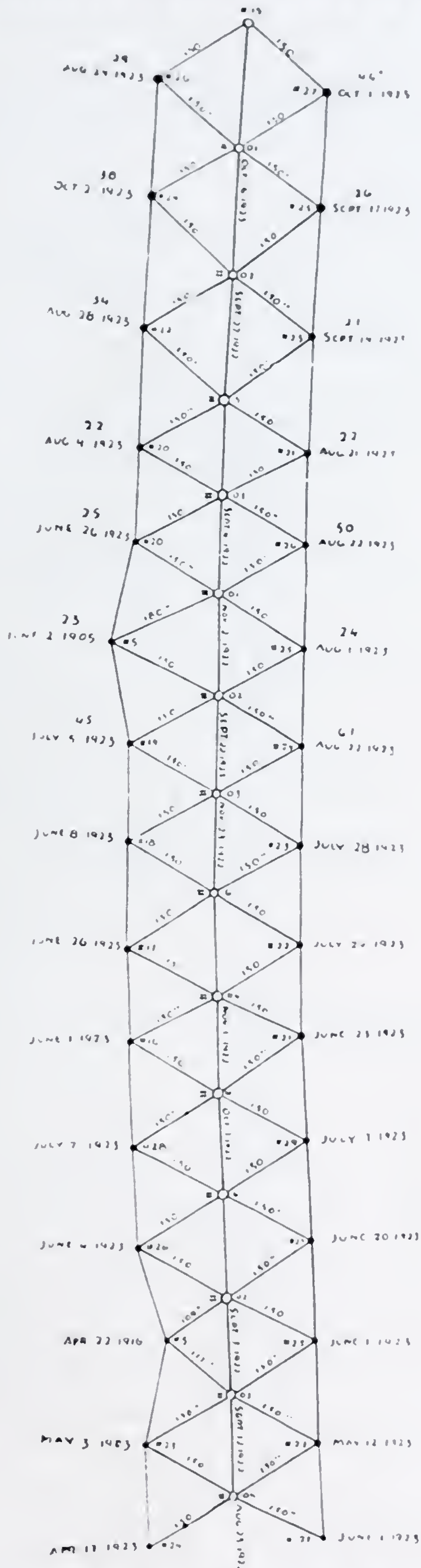

Fig. 2. Wells Spaced for "Line Flooding" at Richburg, N. Y. (After Lawrence E. Smith).

wells are drilled, on the same triangular pattern, in time to catch the increase of oil, while the abandoned oil-wells are successfully turned into water wells.

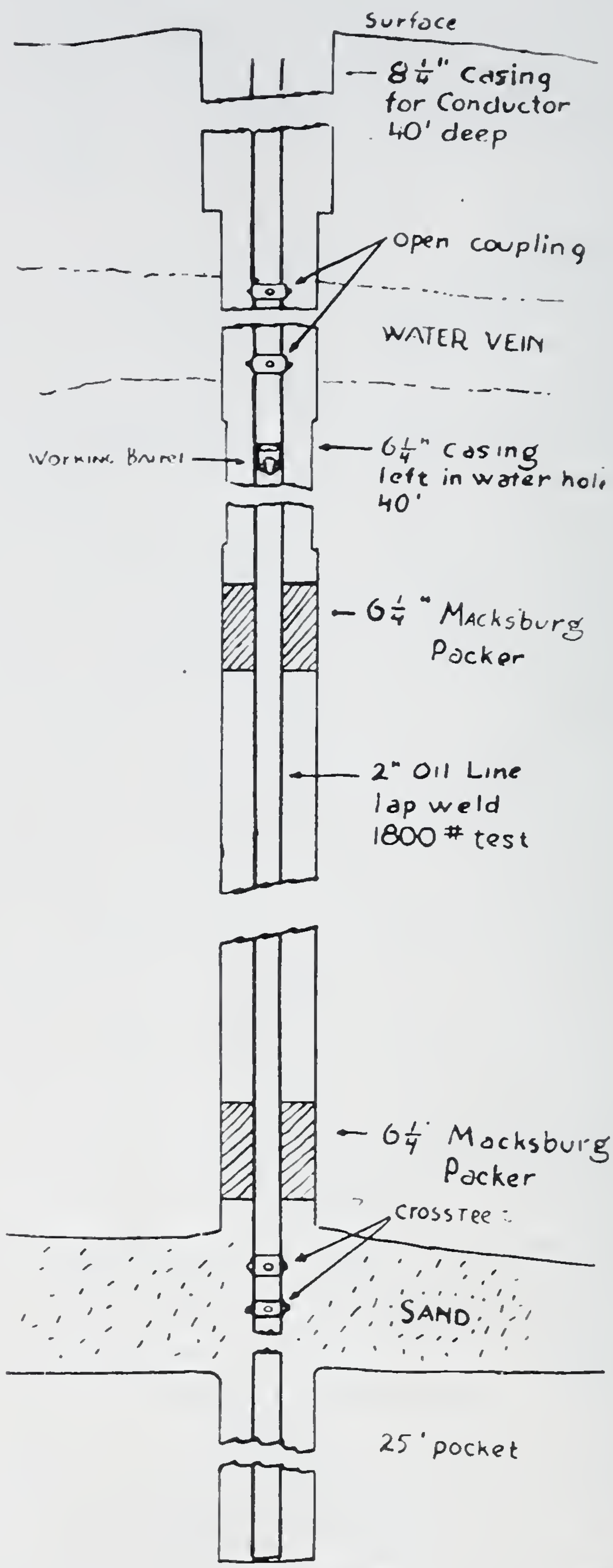

Fig. 3. Method of Equipping Water Well (After Lawrence E. Smith).

The operation of flooding a well consists merely of letting in the ground water, which is abundant and stands within a few feet of the

surface. It generally runs in through properly packed tubing that carries it from the water-table near the surface to the sand at depths of 1000 to 2000 feet. See Fig. 3. A late advance in the method is to put it in under pressure, but most of the Bradford flooding has been done under hydrostatic pressure only. The flood advances at an average rate of 50 feet a year. The daily production of a well is increased several times, but its producing life is rather definitely cut off when the ratio of water to oil becomes too high for economical pumping. Production increases are therefore calculated on the basis of ultimate yield, and estimates vary all the way from 3000 to 12,000 barrels per acre increase of production due to flooding.

The close spacing of the wells is necessary because of the slow progress of the flood. Wells drilled farther apart would not control the flood, nor would they show results in a reasonable time.

The flooding method has been successful at Bradford for three reasons:

1. The sand, though not perfectly even in texture, is nevertheless sufficiently homogeneous and fine grained so that the flood advances slowly and with a fair degree of regularity.
2. The drilling depth is moderate, so that the cost of the extra wells required is not excessive.
3. Water is plentiful.

The latest attempted improvement is to add to the water some reagent to cut the oil free from the sand grains and make more complete the washing of the flood.

Shafts and Tunnels. There have been many oil pools that got production from such moderate depths as 100 to 1000 feet and it is natural that engineers should have thought of applying to them the typical methods of underground mining with shafts and tunnels. Such methods have been used in a small way in Europe for many years and have been most thoughtfully developed at Pechelbronn in Alsace.

At Pechelbronn, oil was formerly obtained entirely through wells. The depth is from 450 to 750 feet and the sand from 7 to 10 feet in thickness. In certain parts of the field, however, considered practically worked out by well-pumping methods, oil mines have been developed. The method is to sink a shaft to the sand, and then drive galleries in the sand on a roughly rectangular pattern with parallel

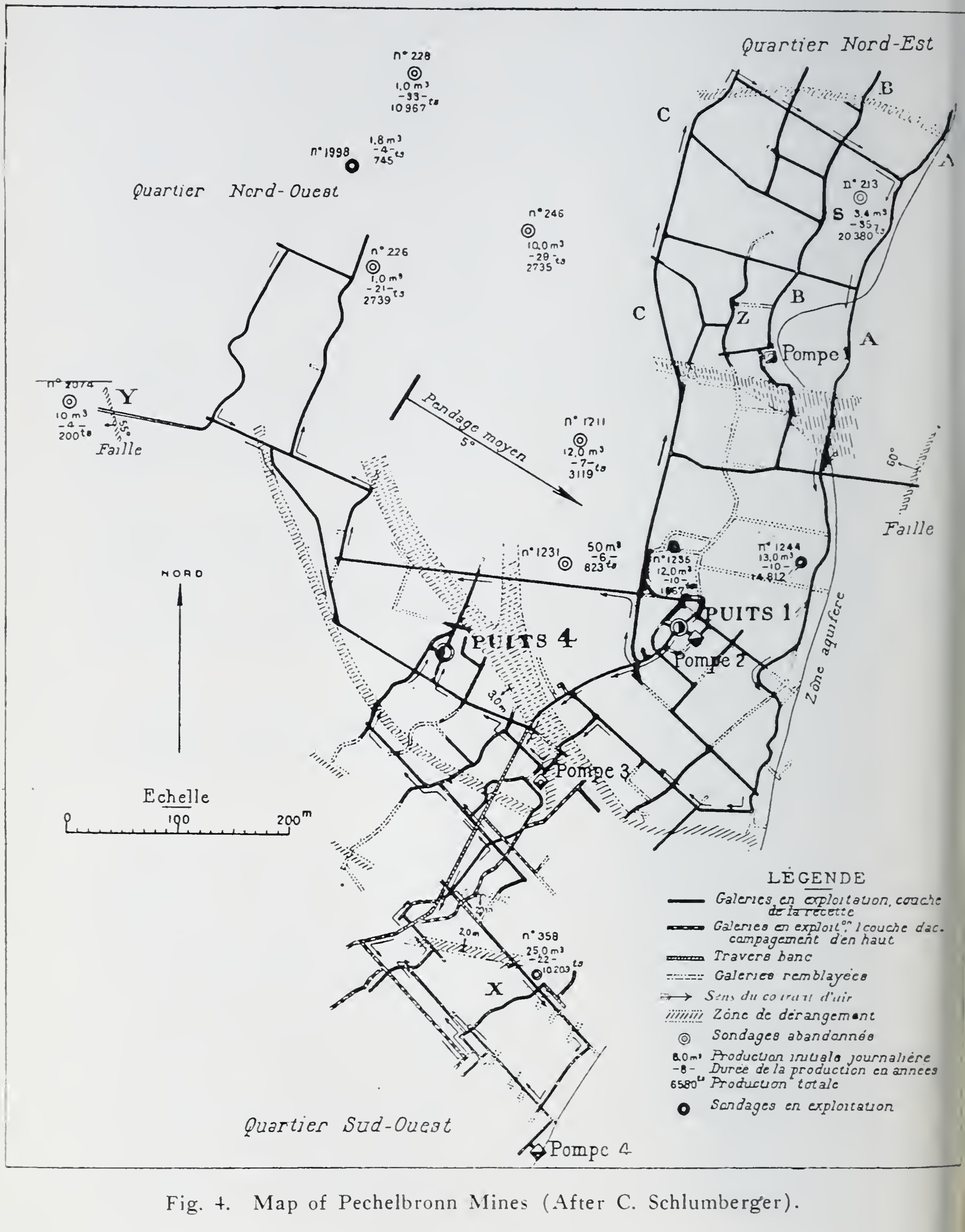

Fig. 4. Map of Pechelbronn Mines (After C. Schlumberger).

entries about 320 feet apart, with cross-cuts every 165 feet. See Fig. 4, a reproduction of a map published in a paper by Schlumberger.* On this map the tunnels ("galeries") are shown by heavy lines. A map appears also in Paul de Chambrier's "Exploitation du pétrole par puits et galeries."†

The galleries are advanced slowly and the oil produced is that which runs into the galleries from the face. The area of the face is about 45 feet and they have obtained 20 to 25 barrels of oil for every linear foot of gallery. The oil runs in rapidly at first, but declines regularly, the flow lasting a few days or weeks, or more rarely a few months. The oil runs into sumps which lead to a pump that raises it to the surface. Timbering is necessary, with many precautions because of the oil. Powerful fans provide ventilation.

This method has been made to pay in Alsace, but it is doubtful if it could be successful in this country because of the hazards and difficulties connected with the essential feature of driving the galleries in the oil-sand. Vapors are present in abundance and are poisonous, inflammable and explosive, in spite of the fact that the oil is heavy and comparatively not volatile. Oil soaks the mine timbers and also makes working conditions very unpleasant. The method, however, has increased the extraction tremendously, one estimate giving 17 per cent. as the yield from wells, and 41.5 per cent. as the additional yield due to mining.

To surmount these difficulties, and at the same time approach the thoroughness of the Pechelbronn method, there have been devised several indirect methods by which the tunnels are drilled near the sand, but not in it. Patents were taken out on such methods as early as 1865. Recently three processes of this class have been developed, these being known as the Ehrat, Ranney, and Rich processes.

The Ehrat method and the Ranney method are essentially similar, but the latter will be described because of the greater publicity it has received in this country. A shaft is sunk to the vicinity of the sand and tunnels are driven either above or below the sand in the compact shale which is usually found as a cap-rock or a floor of a producing horizon. Ranney suggests tunnels in a rectangular pattern, 1320 feet apart, or, in the language of the public-land surveys, sur-

*Chimie et industrie, special number, May 1923.

†Dunod, Paris, 1921.

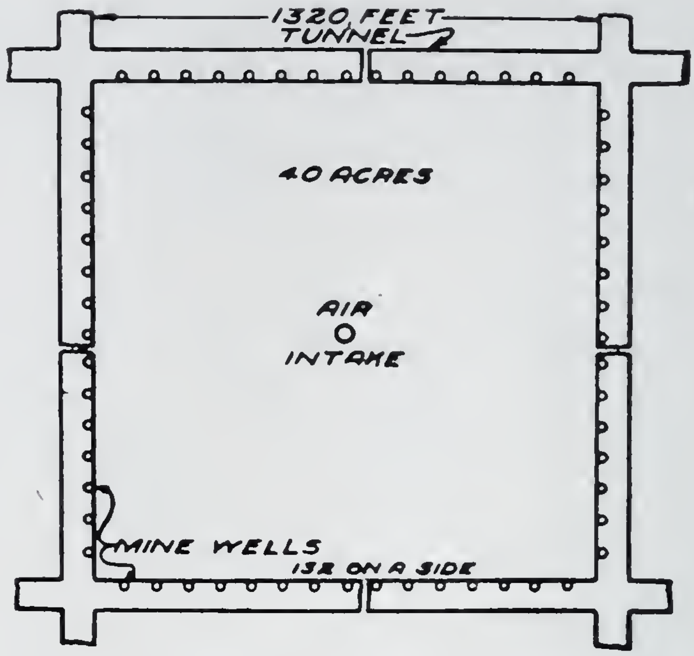

Fig. 5. Diagram Showing Tunnels and Short Drill Holes for Developing a 40-Acre Tract by Ranney Process.

rounding a "40."* See Fig. 5. Location in the cap-rock or floor is made to take advantage of the firmer rock. At intervals of 10 feet, three-inch holes are drilled the short distance to the oil sand, and a two-inch nipple sealed into each hole. See Fig. 6. Then the hole is continued as far as wished into the oil sand, while the nipple is con-

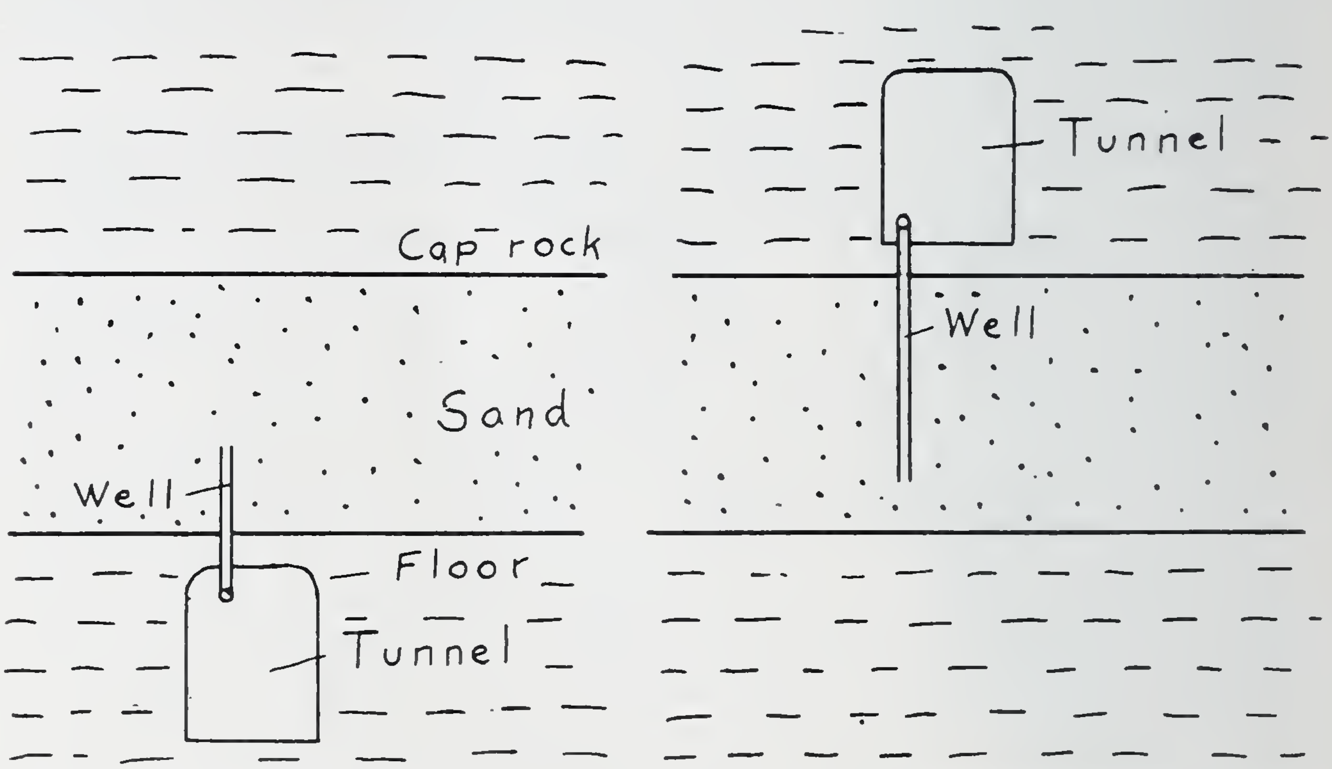

Fig. 6. Cross-Section of Sand Mined by Ranney Process, Showing Alternate Positions of Tunnels (After Leo Ranney).

*Oil and Gas Journal, November 26, 1925, v. 24, p. 107.

nected with a pipe-line running to a pump at the foot of the shaft. If this "mine well" is drilled upward, the oil drains by gravity, but, if downward, the oil has to be pumped. The value of the method lies in the fact that each 40-acre tract is thus drained by 528 wells, instead of the eight or nine of present practice. Several methods of stimulating the flow of oil are suggested, such as running a blind steam-pipe into the sand to heat the oil and make it more fluid, or drilling a well of the usual type in the center of each 40, and then applying compressed air, or a water flood, as previously described. One shaft is considered sufficient for a 2560-acre tract, and on this basis, with the sand from 1000 to 1600 feet deep, costs are calculated to be low enough to permit profitable operation. Mr. Ranney has been working an experimental mine in Jack County, Texas, by this method. Mr. Ranney holds the United States patents for the idea, while Ehrat, a Swiss engineer, has the British and French patents on his similar method.

Rich has recently patented a method similar to this except that, instead of "mine wells," channels are excavated from the tunnels into the sand, a channeling machine of the quarry type being used. Rich claims that the more efficient drainage through the channel will more than offset the extra difficulty of excavation and later fittings. He also makes a special point of the use of compressed air or water, with the much greater control made possible by close spacing of "mine wells" or channels.

Finally, there have been recent patents issued for a method of driving the tunnels directly in the oil sand by the use of a movable shield and air dam which can be shifted forward as the tunnel is advanced.

Surface Mining. Oil-bearing sands are often exposed at the surface by folding and subsequent erosion. Such exposure permits the evaporation of some of the lighter constituents of the oil, but the residue has quite enough of the fractions obtained from oil to have definite value. The residues vary from "live" oil to solid asphalt, depending on how completely the sands have been exposed to evaporating influences.

These outcrops have from earliest times been sources of bituminous materials. The mortar used in the Temple of Babylon was

asphalt, which had broken off the outcrop of the sands now considered to have such important oil possibilities in Mesopotamia and Persia. In this country Indians worked the outcrops in the Appalachian fields; Oil City, Pa., and Paintsville, Ky., both having recognized the remains of ancient workings. Later, tunnels were driven in sand outcrops, in Ohio, and at Sulphur Mountain, in California, for example, to obtain the oil that would run into the passageways.

For modern treatment an outcrop would lend itself especially to mining with steam-shovel. Open-cut mining costs are available in coal stripping, cement-rock mining, and iron and copper mining; and, allowing a moderate cover, it is fair to assume a mining cost of from 20 to 60 cents a cubic yard of the sand itself. To this must be added the cost of separating the oil from the sand. The most promising methods seem to be those requiring washing, either with hot water, as used on the asphaltic sandstone of Kentucky, or water containing some washing reagent, several of which have been used in the flotation processes of mineral separation, and at least one of which (soda-ash) has been tried to increase the efficiency of the Bradford flooding method. The separating and leaching cost would probably not be over 20 cents a cubic yard.

A sand containing 10 per cent. of oil would run about one-half barrel to the cubic yard. Different residues vary too widely in quality to permit a general estimate of value, but it is safe to assume a value sufficient to allow a fair margin of profit over the above costs.

Outcrops containing oil are to be found in many parts of the country. Probably the most notable are the Athabaska tar sands, the outcrop of the Dakota sandstone along the Athabaska River in Alberta, Canada. In the vicinity of Fort McMurray they are found over an area 100 miles north and south by 35 to 40 miles east and west, and often containing from 15 to 20 per cent. bitumen.* On such outcrops there seems to be a definite place for the open-cut method.

By way of conclusion, it is evident that methods of increasing extraction beyond the pumping stage have already reached a rather high degree of perfection. Still, the future will undoubtedly see new methods devised, and the efficiency of the older methods improved. In spite of the importance of the mechanical side of it, there are prob-

*Oil and Gas Journal, December 10, 1925, v. 24, p. 74.

ably no greater needs at present than for better understanding of the real nature of our oil-sands, and more thorough explanations of the workings of the processes above described.

DISCUSSION

W. R. Hart:* I had an opportunity of visiting the oil mine at Pechelbronn on two occasions, and I believe the subject of oil mining deserves a great deal more attention than it has received in our American magazines. Two things impressed me especially—the extremely unfavorable geological conditions under which this first attempt at oil mining has been made, and the very crude and elementary methods used. I don't believe that comparing results at present obtained at Pechelbronn with those of other methods of increasing production does justice to the idea of mining for oil, for I think that if the problem were handled with the amount of initiative and inventive skill that has been applied to our standard production methods much more could be accomplished.

The oil mine at Pechelbronn is a success in spite of the fact that the sands are lenticular, of very moderate extent, have a considerable dip, and are faulted, all of which makes the problem quite difficult.

Results at Pechelbronn bear out M. Paul de Chambrier's experimental work very closely. Twenty per cent. of the original oil content of the sand is considered the maximum obtainable recovery by pumping of wells. A further 40 per cent. is obtained by drainage into the mine workings, and most of the remaining 40 per cent. can be obtained by a treatment of the sand. His experimental work would indicate that all but about two per cent. of the original oil content of the sand could be accounted for in this manner within reasonable economic limits of operation. At present the 40 per cent. recovered by drainage can be obtained at cost so much lower than the remaining 40 per cent. by sand treatment that little attention is being paid to the latter. Some oil is drained from the pile of sand brought to the surface as the tunnels are extended.

I think that the idea of oil mining as a method of increasing recovery should receive more attention in this country. It conflicts in

*With Ralph E. Davis, Consulting Engineer, Pittsburgh.

no way with present methods of production, and in fact can not be applied very well until as much as possible has been recovered by wells, and gas pressure is as low as possible.

N. F. HOPKINS:* How deep are those sands?

W. R. HART: The original workings at Pechelbronn are at a depth of about 450 feet, but the engineer in charge showed surprise at my skepticism regarding the feasibility of working at such depths as 3000 feet with water troubles to consider. He considered the depth as an economic problem. Their mine shafts are lined with masonry or concrete where necessary to meet water and caving difficulties, and he considered a deep shaft as an increased preliminary and operating expense. A new mine they have started is to work sands at a depth of 1200 feet.

The wells at Pechelbronn are pumped by electric power, at a very low cost, till the production is measured in liters. This fits in well with the later mining operations where ideal conditions would be to have the least possible amount of gas left in the sand. The ventilation system originally installed in the first mine was found to be much larger than necessary in actual practice. Parallel main tunnels and cross tunnels are driven, leaving the sand body in blocks approximately 160 feet on the side. Many of these tunnels can be closed off, and need no ventilation during a period of up to four months which is required to drain the oil from these blocks into the conduits under the tunnel floors. Most of the sand from new workings is then placed in these old tunnels instead of bringing it to the surface. The upper surfaces of the tunnel walls drain quickly and the sheet iron back of the timbering along the lower part covers the oil seeping from the lower part into the drains below the floor and prevents the exposure of oil in the tunnels. A large part of the fire hazard is thus eliminated and ventilating problems are somewhat simplified by preventing the evaporation of the lighter constituents of the oil in the tunnels.

With all their pioneering in this field they have had only three accidents of consequence, one of which was due to a failure of the

*Civil and Mining Engineer, Harrop & Hopkins, Pittsburgh.

hoisting apparatus. In their opinion the operations in their mines are no more hazardous than in coal-mines.

I think the methods of increasing recovery described by Mr. Somers might be divided into two classes, the air-drive and water-drive methods being placed in one and the mining methods in the other. The control of the agents used in the first class seems rather uncertain and results difficult to predict. On the other hand, the mining methods, though more costly, give, as we have seen, a much higher recovery, and this recovery, as well as investment and operating costs, can be predicted with a great degree of certainty. There seems to be little left to chance in the financing of an oil mine. The old wells furnish a record of the position and character of the sands analogous to the records obtained in core-drill work on a coal property. The engineers at Pechelbronn claim to be able to estimate recovery of oil before operations are undertaken as closely as they can estimate equipment or operating costs.

M. Paul de Chambrier, who is credited with the development of this system of oil recovery, has an interesting book covering the theory and practice of his method and a study of costs. He has made a study of American fields with a view to the application of these methods. I have made a translation of this book and some technical articles on the subject, but so far I have not been able to get in touch with him regarding his copyright.

Norwood P. Johnston:* I made a little trip with Dr. Somers, simply to look over some of the peculiar oil matters. We watched them produce as high as 50 to 150 barrels a day, anywhere from 75 to 300 feet in the outcrop. With the shallow sands in southeastern Ohio, the great trouble is that the country is so rough that when you find the outcrop it is ducking under the hill with two or three hundred feet of cover on it and no one could get at it on a stripping proposition.

The matter of drift mining into the sand always appeared to be a very hazardous proposition. The oil itself is a very high gravity found right in the face of the outcrop. There are certain places in the United States where some of the high-grade sand can be found in fairly level country, but in these sands the pay has never been found

*Engineer, Pittsburgh.

to be consistent. There is from four or five up to five hundred feet of clay, and the question is whether it would be profitable to start an operation. The only places that seem suitable are the heavy tar sands that are exploited. The question there is the value of the product when it is obtained. If you get only $1 or $1.20, as you do with a great deal of the heavier oil, the mining process would be altogether too expensive.

So far, the best method I have found is the direct application of compressed air, and there are only a very few mines in which it has ever been tried out efficiently. A great many people put air or gas pressure in wells without taking the necessary precautions to cement the tubing or put in sufficient packers, and the air never went into the sand where it was intended to go. There is now a method by which you can more or less control the air after it is underground. If you have a sufficient number of wells, by regulating the pressure on the oil wells, you can keep the air from running away and coming out three or four miles away from where you put it in, which is the great objection to the air proposition. It nearly killed one of our superintendents not long ago. He likes to get up in a warm room in the morning and leaves the gas burning without any window open. His wife was a little more cautious. She went up and opened the window. Air blew in from about four miles away and put the fire out. After the air pressure went off, the gas came back again and the next morning when they woke up their house was filled with gas. That shows how it will travel.

Nobody knows, as far as I know, what the ultimate yield will be from the use of compressed air. I understood Dr. Somers to say that 100 per cent. had been obtained. Is that 100 per cent. of what had been obtained by the flushing and pumping method?

R. E. SOMERS: Yes, I mean they have obtained as much by compressed air as they had obtained by flushing and pumping together.

K. B. CONWAY:* Have you any figures on the percentage of flooding?

R. E. SOMERS: Yes, the figures on flooding are anywhere from 3000 barrels up to 12,000 barrels per acre due to the flooding process.

*Assistant Secretary, Gulf Refining Co., Pittsburgh.

K. B. CONWAY: Additional oil?

R. E. SOMERS: Additional oil. Those figures of 12,000 barrels were for properties that were undoubtedly far better than the standard 3000 barrels at the beginning. They were big leases, so it is probably a 100 per cent. increase, or about the same amount by flooding that had been obtained by pumping.

H. TAUNTON COLES:* I was very much interested to hear about the tar sands of Alberta, Canada. I happened to be in that neighborhood visiting just after the war and I had a look at some. I did not see any of the work started, but some people were going up to exploit the tar sand and I never heard that they had any success. I was wondering if anything in the way of exploitation had been done since. Some friends of mine are interested in the development of the tar sands and getting out asphalt, but they are not after oil.

Also, another thing is the enormous development in Scotland, where they are getting oil from shale. They have been digging it out and roasting it at enormous expense, getting a very fine quality, but no very great quantity of oil.

R. E. SOMERS: About that Athabaska tar sand, I do not think they succeeded in making any recovery of asphalt pay, probably largely on account of transportation troubles. They have tried to get the oil for what it might be split up into in a number of cases. There is a method called the Georgeson process. They drilled a tunnel in a cliff of sand and set up a boiler plant at its mouth. Steam was then led through pipes to the end of the tunnel, where it softened the sand and the tar and gradually found a chamber. The oil ran into a sump and was pumped out. It looked good, but the greatest trouble was that the steam emulsified the oil and left it in pretty bad shape.

The Scotch industry, which has been carried on since 1848, is the ideal of the American oil-shale people. If accomplished successfully there it is reasoned that it must be possible in this country; but Scotland has several features that make for success. In the first place, they have a good market, uninfluenced by 5000- and 10,000-barrel oil-wells such as we have in Texas; secondly, they have been oper-

*Engineer, Charles Hyde & Co., Pittsburgh.

ating since 1848 and they have thoroughly worked out the scientific end, so they know how to retort these shales most successfully; thirdly, they have been skillful about it. They have an industry there that has had its troubles at times. The oil-shale is a peculiar one. There is no question about the amount of oil in oil-shale. There can be the most fantastic tricks played with figures in regard to the oil-shale. It is figured that in the northern part of Colorado and the adjacent parts of Utah there is enough oil in the oil-shale beds (averaging 22 gallons to the ton) to make 40,000,000,000 barrels. If you add the areas that are over the line in Wyoming and Nevada you can double that figure; and yet we figured that all the oil we had available in the beginning was only 15,000,000,000 or 16,000,000,000 barrels. There is a shale called the Chattanooga that outcrops in many of the Appalachian states. In Indiana, where it lies at a depth of 500 feet, you can figure that in that one small unit there are 100,000,000,000 barrels of oil.

N. F. Hopkins: I understand that the first oil obtained in this country was from oil-shale at Darlington, Beaver County, Pa., and near Freeport, Pa.

R. E. Somers: Yes. We started with oil-shale in this country and now we are talking about going back to it.

N. F. Hopkins: Kerosene was first known as coal-oil for that reason. I have seen those Darlington mines and they are still getting out cannel coal. I also saw some of the oil-shale. It is not a profitable proposition to make oil from shale at $3 a barrel. At the time I looked at it oil was $6 and it was being considered that it was possibly profitable to go into it.

Charles R. Fettke:* In connection with a study that I am making of the oil and gas sands of Pennsylvania for the Pennsylvania State Geological Survey, I have had an opportunity to examine several properties where compressed air is being used to recover oil from sands that had practically been exhausted by the ordinary pumping

*Associate Professor of Geology and Mineralogy, Carnegie Institute of Technology, Pittsburgh.

methods. In one case, compressed air has been used for a period of nearly nine years with favorable results. From one to five barrels of oil a day are now being recovered from wells that were no longer paying propositions at the time the compressed-air method was installed. It has also been found that oil-wells can be cheaply and satisfactorily cleaned by the use of compressed air.

In some places where compressed air is being tried out, much better results could undoubtedly be obtained if a more thorough study of underground conditions were made and a more systematic program of applying the air worked out. Sometimes failures have been due to the haphazard methods employed.

I am inclined to believe that compressed air will be found more suitable than flooding for recovering additional quantities of oil from many of the nearly exhausted oil sands of Pennsylvania. Flooding should be employed only as a final resort. It leaves the oil-sand in such a condition that it will be found very difficult, if not impossible, to recover still further quantities of the large percentage of oil which we know remains behind after the sand has been flooded. Undoubtedly, as soon as the price of oil warrants it, such methods as the actual mining of the oil-sand itself, or possibly others that we have not yet discovered will come into use. Operators should be far-sighted enough to keep this in mind in planning their present operations, and keep their sands in such a condition that further future recoveries will be possible.

Cores of the oil-sands have been found to be very helpful in understanding the actual character of the sand and the distribution of the oil in it. The ordinary driller's log has been found to be unreliable when compared with the core tests. Where 30 or 40 feet of sand may have been recorded, the cores frequently show that only a relatively small percentage of this total thickness contains appreciable quantities of oil. The porosity is found to vary greatly. Often numerous thin shale partings, not recorded in the driller's log, are present. A portion of the sand may be absolutely dry, while part of it may be saturated with water and show no oil. It is a very easy matter to overestimate the quantity of oil still remaining in a sand from the amount already recovered, basing this estimate on the total thickness of the sand. In some instances the amount of actual recovery probably represents a larger percentage of the total oil originally

present in the sand than we have been led to believe. In some instances it has been found from studies of cores that, by carefully packing off a portion of the sand, much better recoveries of oil from the remainder have resulted by the use of compressed air. It has been possible, in some cases, to avoid undue losses of air by by-passing in this way.

With reference to the shale-oil reserve of 50,000,000,000 to 100,000,000,000 barrels in the eastern United States, we must not lose sight of the fact that this is present in the form of a very low-grade shale, much, if not most, of which will yield less than 10 gallons of oil per ton. If the rich western shales were located in the eastern part of the country, the early development of an oil-shale industry would offer more attractive possibilities. As it is, the rich shales are located at a great distance from the main centers of consumption in a semi-arid region, where the problem of obtaining sufficient water to develop a large industry will be a very serious one.

Mr. L. C. Karrick, who has made an extensive study of the western shales, is in the audience. You would undoubtedly be interested in hearing from him.

L. C. Karrick:* For the last six years, while employed by the United States Bureau of Mines, I have been occupied in the study of oil-shales, coals, and oil-sands. I should like to emphasize a few salient points of interest in relation to the subject matter of the paper just presented.

I believe the mining engineer is the engineer best equipped to go into commercial oil-shale and oil-sand work. This will seem so if we stop to consider that in the only successful oil-shale industry, as it exists in Scotland, about 60 per cent. of the total cost of producing crude oil is the mining cost. Some of the largest mining companies in the United States are recognizing this point and are preparing to produce oil-shale, and with this in view they are acquiring shale lands. The superior knowledge of mining men will enable them to produce oil considerably cheaper than people not skilled in the art of economical mining. So in anticipation of an oil-shale industry and in recovering oil from sands, I think the mining engineer is the logical man to consider the problem at the present time.

*Refinery Engineer, Pittsburgh Experiment Station, United States Bureau of Mines.

I want to mention a few of my conclusions which might be worthy of your consideration. To begin with, the western oil-shales are considerably richer than the large deposits in the eastern part of the United States, and although it is possible to obtain a great quantity of oil from the western shales, still, at the present time it is possible to deliver crude oil into any part of the oil-shale district much more cheaply than oil can be produced commercially from the shale. There are a few localities where the shale might be mined by open-cut methods and the oil therefore produced at fairly low cost, but in almost the entire shale district it will not be an economic possibility to produce shale-oil to-day. The shale-oils produced under conditions that give the most of the best oil as accomplished so ideally in the Scottish retort will probably lose 20 to 25 per cent. of their volume in refining, whereas crude petroleum loses about four per cent. of its volume by average refining practice throughout the United States. In the shale district there would not be a great market for oil after it is produced and it would have to be shipped to the West or into the Mid-Continent markets and compete with well oil. It seems to me, therefore, that it is not attractive at the present time even for mining engineers to consider a large oil-shale industry as possible in the Rocky Mountain district of the United States. The leaner shales in the East and also the cannel coals are a much better proposition to consider than the richer western shales. There is a large-scale attempt being made in California at the present time to produce shale-oil. It is reported that the company has contracted with a Pacific Coast oil company to deliver about 10,000 gallons of oil a day. The organization has competent technical men in its employ, and they are operating in a locality which possesses some important economic advantages. These shales are not true oil-shale, but are composed of diatomaceous earth impregnated with an inspissated oil residuum. On distillation, a relatively high quality oil is obtained. There is a good market at hand for the products, the shale is mined by open-cut methods, and they have a favorable climate to work in.

An oil-shale industry did really exist in the United States at one time and was located here on the Allegheny River near Freeport. Those shales (really cannel coals), though in rather small quantities, are as rich as the western shales and the oil is of a superior quality when produced by the same distillation methods that the United

States Bureau of Mines found to give the best oils; also, they have the great advantage of water, supplies, markets at hand, labor, and transportation, none of which is available in the Rocky Mountain district.

Another point I wish to make is in relation to the question of oil-sands and the flooding method for oil recovery. Though it may be profitable to the person that floods the producing sands, it must endanger future resources. I have worked on that problem in a laboratory way and my results emphasized the fact that an oil-sand or impregnated rock can either be made to yield its oil, or, on the other hand, the oil may become sealed within the rock. Take for an experiment a lump of dry sandstone and place a drop of oil on it and allow it to soak in. In this case do not allow the rock to become saturated with oil. Set the rock in water, and as the water is taken up by capillary attraction the oil will be displaced and forced out of the rock. Take another piece of rock and soak it in oil it until it is saturated, and place it in water. The water will not have a chance to reach the surface of the sand grains and can not get a foothold for the capillary attraction to become effective and it will not displace any of the oil from the rock. These two physical actions may apply in flooding oil-producing sands. If a big area of producing sand becomes surrounded by water the oil is trapped and probably can not be removed by further flooding. There are channels in the sand strata which the water will follow and possibly trap great areas of oil which can not be made to produce thereafter.

As compared with flooding, the air-pressure or gas-pressure method of recovering residual oil is successful and seems to be without objectionable features. The Smith-Dunn scheme has been applied in many places in the United States. It is quite successful and does not endanger the oil resource or cut down possible future production from the same district by other methods such as mining.

Oil-sands of the type that exist in oil fields which have been abandoned may be treated underground, as our speaker has brought out. In order to recover all the oil in the sand it will be necessary to bring the sand to the surface and treat it by some distillation process. Distillation of the sand *in situ* may work out successfully in some places, but not in others, but for complete recovery the oil-laden sand must be removed to the surface and treated. The Athabaska sand of Canada (one of the largest known bodies of oil-sand) will yield 40

to 60 gallons of oil per ton of sand. The oil is like a heavy tar. After it is removed it is not much good, as it is similar to a very low grade of oil-still residuum. It would be quite a problem to transport this oil in that cold country. There are only about eight months in the year favorable to working conditions because of the cold climate. The consistency of this oil would make it very hard to transport even in warm weather. I doubt if it could be conveyed with pipe-lines, and tank cars would have to be heated in order to empty them. The mining of the tar sand should be possible by steam-shovels and therefore the cost should be in its favor as compared with mining other oil-sands, but after the sand is mined there is still the problem of what to do with it. I believe we have shown that the best way to treat a heavy natural crude oil or residuum to make it useful for petroleum products is to crack it, but it is not profitable to the refiner to crack a heavy oil which yields a great deal of carbon in its decomposition. This kind of oil is one that would yield 10 to 15 per cent. carbon (an excessive amount) in cracking it down to a condition where it is fluid enough to transport in pipe-lines. There is a scheme that was worked out by David T. Day, and also by two of the Bureau engineers, by which they show that when mixed with an inert material such as sand, clay, etc., and simply distilled without confining in pressure cracking stills, a heavy oil will be effectively cracked and rendered quite fluid. The objectionable carbon residue is deposited on the sand grains and not on the walls or tubes of a pressure cracking still. Therefore if one has such a heavy oil and is up against the question what to do with it, the conclusion would be to mix sand with it and distill it. Probably the best thing to do up there is to mine the sand in the cheapest possible way and simply distill it with direct application of heat so as to remove the oil, as this will leave the carbon behind in the sand and the oil could probably then be transported in pipe-lines. A process which attempts to use a light solvent for extraction of the oil from the sand, as is frequently suggested, is working at cross purposes and has many objections.

Now as regards the oil-shales of Utah, Colorado and Wyoming, and the commercial possibilities in treating the coals in that part of the United States: When figures are presented representing the immense amount of oil in the shales, it must not be overlooked that there are many times that amount of oil locked up in the coals which can be

obtained by similar methods of treating. Coal by the same method of distillation will give nearly as much oil as average oil-shales. We usually think that a material distilled from coal is tar, and is quite different physically from the usual conception of oil, because of the type of material formed in distilling coals in gas-plants and in the by-product coke plants. If the coals are distilled at a low temperature, such as is applied in the Scottish shale retort, the coals will give relatively high quality oil or tar, and in most cases the crude oils obtained can be refined to form some of the principal petroleum products. But both the shale-oil and the low-temperature tar-oil from the coal are quite inferior to an average grade petroleum. Likewise tar from a tar sand, even though it be cracked, is an inferior product compared with an average petroleum.

In considering the economic feasibility of producing synthetic oil by low-temperature distillation from shales, sands, or coals, it is pretty much a separate problem in each individual case, being influenced by the market for the products which can be made and by all the other economic factors. The question is not so much the problem of selecting a suitable retort, which we read so much about in the technical press. Commercial success will depend more on the economic factors that surround the plant problem in the particular locality and a correct analysis of these factors.

N. G. Alford:* Dr. Somers has certainly given the Society a most valuable and interesting contribution this evening. With reference to these various methods of secondary recovery that he has detailed for us, I would like Dr. Somers to tell us what he has found as the largest percentage of total recovery in oil on a commercial basis in these various schemes.

R. E. Somers: That is a very hard question to answer in the oil business. As I said before, the measurements are not well made. They are not detailed, and the statements are not strict, and therefore all I can say is that the two methods—compressed air and flooding—have in certain instances surely doubled the amount of oil that otherwise would have been obtained from the sand. The Pechelbronn figure, where 41½ per cent. has been added by the mining method, is

*Vice-President, Howard N. Eavenson & Associates, Pittsburgh.

the nearest to being accurate. I tried very hard, last summer in New York, to get figures from the Bradford flooding method and it was simply impossible.

N. F. Hopkins: Regarding that diagram you showed where the 40-acre tracts were laid out and developed by entries; there are not many places, are there, where that could be applied? The sand does not usually lie in uniform layers.

R. E. Somers: In some fields, yes; in others, no. In Oklahoma and Kansas the sand is practically level, dipping not more than 40 to 60 feet to the mile, as a maximum. The coal measures do not dip much.

N. F. Hopkins: From two or three per cent. up to 6 to 10 per cent. in the Connellsville region.

R. E. Somers: That is to the eastward in the gas region. That means it is a region where oil is not found.

N. F. Hopkins: There is no oil found there, but there is a little gas.

R. E. Somers: Around here and to the west of here, and in West Virginia, most of the sand where oil is found is comparatively level.

N. F. Hopkins: Some of the geological sheets show it as being rather irregular.

R. E. Somers: What is worrying me most is a point one of the other speakers brought out, that the sands are not so regular as they might be. The core test shows that there are layers of shale in greater abundance than we have suspected. Some sands are not very variable in thickness, but they contain patches of shale, and perhaps our figures of 30 per cent. average extraction may not be perfectly fair, because there may not have been 100 per cent. present at the beginning, as we thought there was.

Ralph E. Davis:* I am not a member of this Society, but I hope I will be pardoned for saying a very few words. First, I think Dr. Somers should be congratulated on bringing to this meeting so comprehensive a paper as has just been read. I might say in connection therewith that I have always found it a pleasure to hear Dr. Somers present a paper. He makes his point so clear and so easy that most of us get just what he means. The discussion of the paper has also been most valuable. I might say that I agree with most of the statements made by Dr. Somers and by the other speakers.

There is one point with which I am not wholly in harmony, and that is that the development of shale mining should be left to mining engineers. I am a mining engineer and I have dabbled around with a few of these things. One of the gentlemen Dr. Somers mentioned in his paper as an expert in this matter of mining oil, a few years ago with certain associates, organized a little company. The mining proposition was new and had just been described by the technical journals of Europe and we went out to play the game here. One thing we thought was very wise was to raise enough money to start with to make it a complete success. We raised $100,000 in round figures and we spent all our money trying to find a place where we could make it work, and we couldn't find it. If it is true that the oil-shale industry presents no present profits, but only future hopes, as far as I am concerned, I will let the metallurgical engineers try that game.

H. Taunton Coles: The whole secret of success in the oil-shale mining proposition is the labor cost. They have a much lower labor cost in Scotland than in Colorado.

Norwood P. Johnston: Is it not true that many people believe that a great many minerals beside oil can be obtained by low-temperature distillation of these shales? I think the general public has been led to think that in this residuum you are liable to find anything from diamonds to tooth powder.

L. C. Karrick: Yes, there have been many claims made, and it is chemically possible to produce some of these rare products from

*Consulting Engineer, Pittsburgh.

shale-oil the same as from coal-tar, but they will no doubt cost more than they can sell for, and there is not enough market in most cases to warrant producing them. As regards rare metals, there is gold in the shales from the Green River formation and in other oil-shales. There was at one time a lot of publicity given to the claims of gold, silver, and platinum existing in oil-shales. I was given a part in the job of the Bureau finding out whether these rare metals were present or not. Some people who claimed to have obtained a large quantity of gold and some silver and platinum, selected a shipment of their oil-shale, assisted by one of our Bureau of Mines metallurgists, and the shale was turned over to me. The people claimed that the process they were interested in had the unusual feature of "unlocking" the metal values and the rare metals could not be obtained by other metallurgical methods. One of the promoters' engineers directed this part of our investigation. We independently analyzed the sample by commonly accepted metallurgical treatments, and in all cases the returns were 20 cents in gold per ton of oil-shale, and no silver or platinum. To obviate any possibility that gold in the form they imagined it to be present could be volatilized even at low temperatures, we digested the entire organic constituent of the shale with chromic acid, and the results were the same. That was the same shale from which they claimed to have obtained seven or eight dollars per ton in gold, and considerable silver and platinum. I doubt very much if there is any accumulation of gold excepting possibly in little seams in the beds. Realizing the origin of the shales, I do not doubt that there could be a concentration of gold in seams or crevices, but there is no great quantity of rare metals.

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VARIOUS METHODS OF CUTTING COAL*

By W. R. Jarvis†

Instead of attempting to write a comprehensive paper on this subject my hope is that I may be able to bring up a few points which will lead to a discussion that may be interesting to you.

The problem of machine cutting in a bituminous coal-mine is one that is receiving a great deal of careful attention and investigation on the part of the coal operators at the present time. It is a problem that is complicated by many different conditions in the mines. The character of the top, the bottom, the coal seam being worked, and the question of lump coal all enter in as determining factors and, in addition, the preparation of the coal so that it can be loaded mechanically is more and more becoming a consideration in many mines.

I think it may be said that there are two general systems of mining used—the long-wall and the room-and-pillar, with many modifications of each.

The true long-wall system is not being used to any extent in the mines in this vicinity and never has been except in a few isolated cases. It is so entirely different from room-and-pillar work that it calls for a different knowledge and experience of mining and, I believe, many failures of it can be attributed to the fact that men not trained in it have been depended upon to work out the problem. Men familiar through long experience with the room-and-pillar system of mining are not qualified to take charge of and work successfully a long-wall system, just as the opposite is true. To operate a long-wall face or faces, to handle the top, and overcome the difficulties which are sure to arise, the supervision of an experienced long-wall man is necessary, frequently assisted by other men also experienced in the work.

I believe that in time to come the long-wall method of working will be more and more used, especially in our low coal seams, and that the use of conveyors at the face will become more prevalent. The same is in a measure true of modified long-wall work in panels either advancing or retreating. Some very interesting experiments have been and are being carried on along these lines in both high and low coal

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†Sullivan Machinery Co., Pittsburgh.

and, from the results obtained so far, it certainly appears that some of them will be successful.

Any long-wall or modified long-wall work means bottom cutting, and for this a regular design of long-wall machine so far seems the only practical method of preparing the coal for shooting. With this type of machine, an undercut is made from three feet to six feet in depth, depending upon the bottom and top conditions, and as the machine itself requires only 30 inches between the face and the props or conveyor it is possible to leave a minimum amount of unsupported top. It is not a fair test to experiment on a long-wall face with a machine designed for room-and-pillar work and one that requires six feet of space in which to cross the face, as has been done in some cases, for the results obtained will necessarily be misleading.

In the room-and-pillar system we have two separate conditions applying to the wide or room work on the one hand and to the narrow or entry work on the other, and in some cases where the ribs are split this means more narrow work than is the case where the entries and rooms are clearly defined with a later pulling of the pillars.

The machine cut with modern cutting machines can be put in at the top of the seam or near the top, in or near the middle of the seam, or in the bottom.

Cutting in or near the top means the use of a track-cutting machine with a cut from six to nine feet in depth. I believe conditions requiring a top cut are very limited and are confined to places where there are many impurities in the bottom coal, making it very difficult for the bits to stand up, but where the coal is soft at the top and a top cut can be easily put in with the coal shooting readily from the bottom. As a rule, coal will not shoot up as well as it will shoot down. When very bad and frequent rolls are encountered in the bottom there is also a field for top cutting, but the problem of an irregular bottom on which to load must then be faced. It is also desirable and necessary in some cases to leave coal up to protect the roof, and top cutting is done for this purpose, but I believe the roof protection can be better accomplished in another way to be mentioned later.

I can see no application of center cutting unless the seam contains a dirt band, comparatively soft and easily cut, which can be cut out but which can not be readily separated when the coal is undercut.

The undercutting of coal is of course the practice most generally followed in rooms and entries, and good results have always been obtained from the bottom cut, and especially so since using machines which cut continuously from one side to the other, leaving a clean cut of six inches in height and from five to seven feet deep under the entire body of coal in the working place, and with no sprags or uncut portions. This kind of an undercut more nearly approaches that put in by hand and later by the punching machine. Some attempts have been made to snub coal after an undercut and while this causes the coal to roll out better when shot, it is done only with considerable added expense which will probably offset the advantage gained.

In order to increase the cutting speed—especially so in places from ten to fifteen feet in width, and in entry work—track-cutting machines are being used to advantage, and more places can be undercut in a shift with a machine that cuts directly from the track than with a machine which has to be unloaded from the truck in each place.

Closely connected with the practice of undercutting the coal with a track machine is the question of shearing the coal, as well. I do not think there are many, if any, conditions where shearing by itself is a satisfactory method of cutting coal preparatory to shooting, but a shearing cut with an undercut has, I believe, many applications and advantages.

Where the top is bad, but will stay up if protected by six or eight inches of coal, undercutting and shearing can be used to advantage if the shearing cut is put in close to the middle of the working place. In a working place from ten to eighteen feet in width a shearing cut in the middle with an undercut necessitates only two shots in the face, thus eliminating the drilling of one shot hole; reduces the amount of powder used by at least one-third; permits the arching of the top; and saves a tremendous timbering cost. This arching of the top coal, all important when coal left up will hold the top, can be effected only by the use of the center shear, and results obtained along this line under some conditions have been surprising.

Another application of the undercut and center shear is in the preparation of coal for the loading machine, for, after the face of the coal is cut in this way and properly shot, more lump coal can be obtained and at the same time the entire face loosened up so that a loading machine can be worked effectively. To enable a loading

machine of the average type to load the coal from the face this coal must be thoroughly loosened up and not partly shot down with a portion left hanging to the solid. On the other hand, in commercial coal-mines it is a serious matter when the coal is broken up with a large percentage of slack and small size—and the more powder it is necessary to use the greater the amount of slack, to say nothing about the damage that may be done to the top.

While a center shear is necessary when protecting the top is the main consideration, there are conditions when a center shear is not as effective as a side shear in preparing the coal for a mechanical loader, and this condition exists where the coal has lateral cleavage planes and tends to hang up on the sides when shot to a center shear. In some cases it has been found that two shearing cuts can be put in to advantage in a wide room, and the results obtained in 30-foot rooms with an undercut and two shearing cuts aided materially in the preparation of the coal for a loading machine. In the place to which reference is made the center block of coal breaks with almost no shooting, as there is a good parting at the top, and two light shots on each rib prepared the coal for loading and also increased the amount of lump.

I think it has been pretty thoroughly proved by experiment that under most conditions bottom cutting of coal, supplemented by shearing, has given the best general results, and the advantages can be summarized as follows:

1. Better protection to the top.
2. A smooth bottom on which to load, especially important in mechanical loading.
3. Better preparation of coal for mechanical loading.
4. Increased percentage of lump coal.

Some figures were given out some time ago which would seem to show that the extra slack made by the shearing cut was an important factor, and in this respect these figures were misleading, as were also some of the figures on the final results. In order to make a comparison of this kind we must consider coal of the same height, undercut to the same depth whether sheared or not, and rooms or entries of the same width.

Figuring on the basis of machine cutting in a place 12 feet wide, with coal seven feet in height, and undercut and sheared nine feet

(considering 27 cubic feet of solid coal equal to a ton), we have 3.08 tons of cuttings, or 11 per cent. The same place undercut will make two tons of cuttings, or seven per cent., or a difference of four per cent. only in amount of machine cuttings. In an 18-foot place, with the same height and the same depth of undercut and shear, we will have a difference of only 2.6 per cent. in machine cuttings and the lump coal will be found increased by from 15 to 20 per cent. These figures are based on a 5½-inch kerf breaking out six inches, and there is no reason why a shearing cut should be any wider than this; in fact, some machines operate with only a five-inch undercut and shear.

A track-cutting machine with suitable tracks at the face will cut as close to the bottom as a room-and-pillar machine, and, if the shearing cut is carried through to the bottom, what little bottom is left will readily come up, or at least will come up more easily than without this shear.

It has also been demonstrated that with hand loading, more coal can be loaded per man when the place is undercut and sheared, due first to the better preparation of the coal for handling (eliminating almost entirely the necessity of using a pick), and second, the saving in time devoted to dead work of setting timbers and moving slate.

Some interesting figures were furnished by a mine in western Kentucky from data obtained by carefully screening and weighing the coal, and these figures were tabulated as follows:

	Without shear per cut per cent.	With shear per cut per cent.
Prime lump 6 inches and upward	19	38
6 by 3 inches	30	18
3 by 1¼ inches	17	15
1¼ inches and under	34	29

It will be noted that there was an increase of 19 per cent. in the six-inch lump coal, and a decrease in all the smaller sizes, including the fine coal or slack, which in this case made a difference in the value of the coal considerably above the cost of shearing. These figures check very closely with those obtained from an Illinois mine, except that the screenings were decreased by a larger percentage, while the

difference was mainly in the lump coal, the small size remaining about the same as without shearing. In this same district the results obtained from top cutting and shearing were not as good as from undercutting alone, the screenings increasing after the top cut and shear.

There is one very important factor in the success of any track-cutting machine, and that is the kind of track that is laid at the face and the care that is exercised in laying the track. A track-cutting machine will not work on wood rails, or light steel rails, or rails simply thrown down and not securely fastened to ties. Not less than 16-pound rails should be used at the face and, when steel ties are used, a section of rails 20 feet long can be kept at each face and moved up after each cut, and the space between the permanent rails and the steel tie section bridged over after each move by using two rails tapered off at each end and fastened to the sides of the rails with hook bolts. In this way both rails will always be an equal distance from the face, and not so many different lengths of short rails will be required in keeping the track at the face.

Another way of accomplishing the same result is to lay the rails at the face on their sides, overlapping the permanent track and on the inside of it, and spiked in place on the last tie or ties. The flanges of the wheels will then run in the groove of the rails and one side of the rail will be forced into the bottom, serving to hold it. I believe, however, that the best results can be obtained from the steel ties, as less skill is required on the part of the track layer.

To summarize, there is a tendency towards the use of revolutionary methods of cutting coal, and this tendency should be given careful consideration by operators so as to determine which of the following is most feasible:

1. The introduction of a long-wall or modified long-wall system, using long-wall mining machines and face conveyors.

2. The introduction of a shearing cut put in by a shearing machine as a complement to an undercut or a top cut.

3. The use of a combination track-cutting machine which will both undercut and shear.

DISCUSSION

Graham Bright:* Mr. Jarvis mentioned 16-pound rails to be used for the last section. I would like to know what he thinks should be used up to that last section. It seems to me that sounds a little light for a rail cutting machine.

W. R. Jarvis: I said not less than 16-pound rails. I would very much prefer 25-pound rails. They can not be too heavy, within reason, at the face to give proper support to a track-cutting machine. Very often 12-pound rails and even wooden rails are used, and these are altogether too light.

E. H. Coxe:† May I ask what kind of a cut you get when using a track machine in a 30-foot room, and what sort of a face you get?

W. R. Jarvis: I would say that a 30-foot room was too wide to cut with a track-cutting machine unless two cuts were made, and this would necessitate a double track in the room. I think the limit of room width for track-cutting machines would be from 18 to 20 feet. Any wider room would call for the use of a bar so long as to be impractical.

E. H. Coxe: A nine-foot cutting bar would make one cut.

W. R. Jarvis: Yes. A nine-foot cutter bar would cut a room of this width in one cut, though you would have a slight arc at the face.

E. H. Coxe: How does that shoot where you have a straight cleavage face in the coal?

W. R. Jarvis: The coal will not shoot as well in a 20-foot room as it will in a 15- or 18-foot room. In rooms or entries up to 15 feet wide, the arc at the face is so slight that the coal shoots readily and breaks cleanly.

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†Mining Engineer, Uniontown, Pa.

L. F. Crawford:* I would like to ask how you place the shots in shooting a shearing?

W. R. Jarvis: The shots are placed about two feet from the top and eight to ten inches out from each rib. These shots when fired do not break the top or the top coal, but do break the coal from the rib.

Harry J. Lewis:† I always like to listen to these discussions of long-wall and room-and-pillar. The successful long-wall has always been in thin veins, as I have seen it, and people who use long-wall in thick veins almost always drift back to room-and-pillar. I think it may come from the difficulty in controlling the big displacement of top in thick-vein coal. The smaller displacement of the thin vein seems to lend itself to the bending rather than the breaking of the top, which must occur in dropping the top anything over 4 or 4½ feet.

L. D. Tracy:‡ To-day I was talking with a gentleman who visited England some months ago and he told me of an incident in which a mine superintendent was brought from a long-wall district to inaugurate the same system in a mine which had been using the room-and-pillar system in a thick bed. He was unable to find material for pack walls and so was unable to make a success of long-wall mining in that particular mine. As I understand long-wall and as I have seen it in Illinois, it seems to me that pack walls are the main essential, and the trouble in this part of the country where the coal bed is thick is that there isn't dirt and slate enough to make pack walls close to the face, and without pack walls I do not believe you can make long-wall mining a success.

W. W. MacFarren:§ In the shearing and undercutting of which you spoke, I should like to ask whether the undercutting and the shearing are both done with the same bar?

W. R. Jarvis: I was not speaking of any particular machine. There are some machines which undercut and shear with different

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§Mechanical Engineer, Pittsburgh.

bars and other machines which undercut and shear with the same bar. There are several different types of machines designed for this work. I think about 50 per cent. of them use one bar and the other 50 per cent. use two bars.

W. W. MacFarren: The same machine with two different bars, or two different machines?

W. R. Jarvis: Both ways. Some machines have been made with two bars and others with a bar that swings, the same bar putting in the undercut and the shearing cut. There are also other designs where one machine does the undercutting and another machine does the shearing. They are all being tried out.

W. W. MacFarren: Have you in mind any particular machine that will do the undercutting and the shearing both in a place as wide as 30 feet?

W. R. Jarvis: No, I do not know of any such machine. In that case it would be well to use a regular room-and-pillar, continuous-cutting machine for undercutting the place, and then use a shearing machine to shear the place either once or twice. In the place I spoke of in Illinois they used a regular undercutting machine and then sheared the place twice.

Graham Bright: I would like to ask if it is possible to have a diagonal face in the room and run the track up along the face and use the track-cutting machine and get your large room in that way?

W. R. Jarvis: You mean driving the face of the room at an angle instead of carrying it at a right angle with the rib?

Graham Bright: Yes.

W. R. Jarvis: This has been done in several places in West Virginia, and almost any machine designed to slab from the track would operate under this condition. One difficulty I have heard of seems to be in maintaining the angle of the face.

E. H. Coxe: In driving a place in that way, does it not make difficult shooting? Does anybody have any information on that subject?

W. R. Jarvis: Is not that affected by the cleavage of the coal? Some coal will shoot on the diagonal, and in other cases you have pronounced butts and faces and it is more difficult then. I think it depends entirely on the seam of coal.

E. H. Coxe: I think the answer to that would be that you would have to have the room at the angle to the cleavage face so that the long face would be parallel with the cleavage, but that would still make it difficult in getting out that back point. I imagine that would make a good deal of picking in the corner. I have seen plans prepared for that kind of work, but I have never seen the actual work done.

N. F. Hopkins:* Wouldn't the sharp angle be equivalent to narrow work in that case?

E. H. Coxe: No, I do not think it would because you would have the long face.

Graham Bright: Instead of an angle you would have a big curve.

Harry J. Lewis: That is the reason why they did away with it in West Virginia, because the coal down there is cross sheared and it falls out in vertical fingers from the working face.

Edward Steidle:† May I ask Mr. Jarvis whether he knows of any operation where they have eliminated shooting by improved methods of undercutting and shearing?

W. R. Jarvis: No. They have cut down the amount of powder used, but I do not know of any place where they have eliminated shooting entirely. I was told, a few days ago, of a place in Illinois

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where they sheared the face twice to determine the increase in lump with this method and then the center block of coal was pulled with a light shot.

EDWARD STEIDLE: Is it not possible under some conditions with a modified long-wall face to eliminate shooting by improved methods of shearing and undercutting?

W. R. JARVIS: It would be difficult to shear the average long-wall face. The shearing cut must be put in at a right angle to the face cut, and to do this would require more room than would be available on a long-wall face.

W. W. MACFARREN: I might endeavor to tell you how that might be done. If you undercut a long-wall face with a long-wall machine you can shear back to the back end of your undercut, or near the back end, any proportion of the height of the seam you want to shear by a shearing bar fastened to a loading machine which is working parallel to the face. This might in some cases eliminate shooting, as the coal might fall. I did not quite get the question of the gentleman who asked you if you had ever heard of eliminating shooting by shearing. If the cuts were sufficiently close, that could be done. While I am not ready to say much on the subject, I will indicate that in working a long-wall face as just described with a shearing bar on a loading machine, the bar being parallel to the face, if hydraulic jacks were placed on the front end of the bar, then after the coal has been undercut and when it is sheared to a depth of two or three feet the jacks would break down that coal in very nice shape for loading.

N. F. HOPKINS: When using the two shearing cuts should the center be shot first?

W. R. JARVIS: Yes.

N. F. HOPKINS: Then the side cut?

W. R. JARVIS: Yes.

N. F. HOPKINS: Machine loading?

W. R. Jarvis: They do all the shooting before the loading machine goes in.

N. F. Hopkins: In the long-wall system is there an advantage in having the wall parallel to the faces of the coal instead of parallel to the butts? Does the coal break down any better?

W. R. Jarvis: Yes. I think there is much difference in the way the coal shoots due to the nature of the coal. I would rather hear from some of the mining men here. They can tell you more about the breaking of the coal that way than I can.

N. F. Hopkins: Rooms are usually against the face and parallel to the butts. Can anybody answer that? What is your opinion, Mr. Lewis?

Harry J. Lewis: I think Mr. Jarvis put it very well; the conditions and the hardness and the cleavage of the coal make a difference and you can not set up any general rule.

W. R. Jarvis: Out in Iowa they cut circular long-wall.

W. W. MacFarren: And they get a pretty high percentage of lump.

Graham Bright: The use of the storage battery for cutting may speed up the use of high-quality steel in bits. This is being done by the Consolidation Coal Company, and it has been found that sharp bits take not much more than half the power of the bits when dull. When you use battery power you have to save every bit of power you can. They have found that by using a better grade of steel, and changing bits oftener, there is a great saving in battery power. They are able to cut 18 to 30 places in a night with one battery, which they could not do with ordinary steel if they let the bits get dull.

Harry J. Lewis: There is one thing that will always work against shearing alone. Shearing does not relieve the weight. The coal is just as tight after you shear it vertically as it was before, and

the main object of cutting is to relieve the weight and get some space to receive your coal when you shoot.

N. F. HOPKINS: I believe cutting the roof sometimes leaves a little piece of coal up that prevents too rapid breaking down of the roof, does it not?

W. R. JARVIS: Yes. It has been demonstrated in some cases that leaving up a few inches of top coal preserves the roof by preventing the air from reaching it, and to do this, top cutting alone can be done successfully. The point I tried to make was that in narrow work bottom cutting and shearing accomplish the same results with additional benefits. When you cut a place near the top it will shoot out wider at the top than at the bottom, whereas when a place is undercut it will shoot out wider at the bottom than at the top, and shearing in addition to the bottom cut, with the resulting lighter shooting, tends to make this condition more pronounced, with a definite narrowing at the top; in fact, considerable coal is left in the upper corners.

FURMANITE*

By Oliver L. Gilbert†

One day about a year ago in Newport News, Va., I saw the maintainance engineer of the largest shipyard in America looking up at a leaking joint in a six-inch steam line suspended 20 feet in the air. To me it looked like an overtime job that would cost well over a hundred dollars before he was through with it, but he grinned cheerfully at my condolences and told me that repairing leaking joints was not the problem that it used to be, and that if I cared to wait for a few minutes one of the boys was coming over to shoot it with Furmanite. While we were waiting for the pipe-fitter he explained to me that the very bad leak under consideration would be permanently closed with about ten cents worth of material and a labor expenditure of not over 70 cents, without shutting off the steam pressure or interfering with operation in any way. The pipe-fitter arrived while we were talking, set up a few tools on the blowing joint, screwed down on the plunger of the Furmanite gun, and the leak stopped. The blowing steam simply faded away, gave one last sputter, and quit. In less than half an hour from the time the pipe-fitter had placed a ladder up against the pipe he had removed all of the tools from the joint and was on his way back to the shop. The joint was tight with not even a slight "weep" of steam—all done by one mechanic in less than thirty minutes, and the operators in the mill which was served by the steam-pipe did not know that the pipe was being repaired. I agreed with the maintenance engineer that repairing leaking joints was not the problem that it used to be.

I asked him why I had never heard of this Furmanite thing before; why there was not a set of leak-sealing tools in every powerhouse and industrial plant; why so many plants were still repairing leaking joints by shutting off the pressure, unbolting the joint and installing a new gasket between the flanges. His answer was very logical. The Furmanite method of sealing leaks was comparatively a new idea. Both the sealing compound and the leak-sealing tools and equipment were but a year out of the development stage. Only a few sets had been put on the market; in fact, the set that his men

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†Sattley & Gilbert, Pittsburgh.

were using was one of the first sets sold, and the thing was going slowly because leaking joints had been repaired in the same old way for two hundred years, and people would not believe it when they were told that it was both possible and practical to seal leaks by means of the local injection of a sealing medium without unbolting the joint or cutting off the pressure. My engineer friend admitted that he had scoffed at the idea until he had witnessed a demonstration. So would I have doubted had I not seen the demonstration first.

The principle of Furmanite leak sealing is very simple, both in theory and practice. The outside or discharge end of the leak aperture is partly blanked off by means of baffles to prevent the escape of the leak-sealing compound into the atmosphere. The Furmanite leak-sealing compound is forced into the leak under a very high pressure by means of special pressure guns against the pressure within the pipe or container. The leak-sealing material is so compounded that it becomes semi-fluid when it is first heated, so that it can be injected into the leak under high pressure. It quickly vulcanizes under the continued application of heat and sets up solidly, completely filling, with a molded gasket, the aperture through which the steam or other fluid has been escaping. This molded gasket adheres to the broken edges of the original broken gasket and to the flange faces and permanently seals the leak aperture against the further escape of the fluid within the pipe or container. The vulcanization process requires from 10 to 15 minutes, after which the pressure gun, baffles, nozzles and other devices used in the injection operation are removed from the joint, taking away all metallic and mechanical devices and leaving nothing behind except the Furmanite which has closed the opening through which the fluid was escaping.

Furmanite is a compound put up in cartridge form. It is manufactured in three different sizes, to fit the various pressure guns which are included in the standard set of Furmanite leak-sealing equipment. It is not a cement or metallic compound in any respect, but, when hardened by vulcanization, possesses the properties of high-grade packing. Furmanite softens to a workable condition at 180 degrees F. and has been used very successfully for sealing leaks under 300 pounds steam pressure, or 417 degrees F. The compound will remain plastic and can be worked for about 45 minutes at 180 degrees, while vulcanization starts in from 3½ to 4 minutes at 417 degrees.

Furmanite has the property of adhesion to a remarkable degree when it is applied under pressure to other packing or metallic surfaces. When a leak is sealed in a joint where the original gasket has broken through, the high injection pressure forces the compound into the broken edges of the leaking gasket and vulcanizes tightly to it. The compound is also actually forced into the minute pores of the metal flanges and cements securely to the faces of the flanges themselves. For this reason the patched section of the old gasket through which the steam or water was formerly leaking is frequently stronger and will last longer than the unbroken portion of the gasket.

Furmanite was originally compounded for sealing leaks in steam joints. It is also particularly suitable for sealing leaks in fresh-water, salt-water, and compressed-air lines, and has been used successfully in repairing oil and gas installations.

In order to inject Furmanite into a leak, and to hold the semi-fluid compound in the leak and prevent its escape into the atmosphere until vulcanization takes place, special pressure guns, tools and equipment are required. After the sealing compound, the proper methods of injection, and the injection apparatus had been worked out and perfected, a year's test in sealing all the leaks that occurred in the power-house and pipe-lines of a large industrial plant convinced the inventors that the principles and methods of leak sealing by Furmanite were highly practical and of high economic value to industry. It was when they began making plans for the presentation of their discoveries to the industries that the engineers were confronted with their biggest problems. Investigation showed that there were nine standard kinds of flanged pipe connections, which, when the sizes in common use were considered, gave 158 different standard flanged joints. Besides these there was almost an indefinite number of special or odd flanged joints in use, and a great multiplicity of other bolted flange connections such as cylinder heads, covers, manholes, etc. Blow-holes, sand holes, porous spots and small shrinkage cracks in castings were also easily sealed with Furmanite; but in the experimental and development work one of each standard kind of flanged joints was used, and tools developed for sealing leaks in these experimental joints. During the year's test in plant and power-house operation some attempt had been made to simplify and standardize the leak-sealing equipment that was required, but the engineers and mechanics

found it necessary to be continually making extra baffles, nozzles, holders, etc., to take care of new conditions that were always arising because of varying conditions in style and dimensions of joint, and because of the location of the leak in respect to the working space available. The engineers realized that in order to make Furmanite available for use in power-houses, on ships, or in manufacturing plants, a set of equipment must be developed to meet the following requirements:

1. The equipment must be universal in its range of application. It should be applicable for sealing leaks in any of the nine different kinds of standard pipe-flange connections in any of the sizes that might be used in any plant. It should also be adaptable for sealing leaks in practically all special and odd flanged joints which a repair man might find leaking, as well as the bolted cylinder heads and similar bolted joints. Likewise it must also be flexible in its application, so that the leak might be sealed by setting up the equipment on the joint in a number of different ways. Leaks often break out in cramped and inaccessible locations, and the equipment set-up must conform to the available working space.

2. The equipment must be inexpensive, so as to be within the price limit of the small manufacturing plant.

3. The equipment must be simple and easily operated. It must be so designed that any mechanic of average intelligence can operate it successfully by following easily understood printed instructions, and not require a trained or highly skilled operator.

4. The entire equipment must be portable and easily moved from shop to leak and from leak to tool-room.

5. The parts must be of simple, rugged construction, with a minimum of pieces, and the entire set must be durable and as nearly fool-proof as possible.

6. Above all, the tools must *work*. They must be sufficient to perform the service for which they were intended, easily and economically with a minimum time and labor requirement. They must be flexible in their application and capable of sealing all of the leaks that occur in the flanged connections of pipe-lines, cylinders, etc., and have a wide range of usefulness for sealing difficult and unusual leaks in all kinds of equipment.

A careful checking up of operating pipe-lines and equipment in a number of representative plants in the various industries using pipes and other pressure containers showed that the leak-sealing equipment should have a range of application to standard, low-pressure flanged joints in pipe of all sizes. By standard, low-pressure flanged joints we mean the joints made by standard companion flanges, valves, and fittings with plain-faced flanges that are made up with a full gasket that is pierced by the flange bolts and is approximately the same outside diameter as the flanges themselves. These plain-faced companion flanges, valves, and fittings are usually made of cast-iron or brass and are most frequently used in piping installations carrying working pressures up to 125 pounds steam pressure or 185 pounds air, water, gas, or oil pressure. In ship construction, however, steel flanges, valves, and fittings for higher working pressures are often made with plain faces.

The equipment should have a range of application to standard, extra-heavy and high-pressure flanged joints in pipe ranging in size from ¾ inch to 18 inches. Under the head of standard, extra-heavy and high-pressure standard flanged connections are companion flanges, valves and fittings with low raised-face flanges, high raised-face flanges, tongue-and-groove flanges, male and female flanges and the Van Stone or lapped pipe joint.

These extra-heavy and high-pressure joints are almost always made up with ring gaskets which are not pierced by the flange bolts, but are smaller in outside diameter than the bolt circle of the flange. The gaskets may be of packing material, copper, asbestos, or combination metal and packing fabrics. In some cases a machined, ground, metal-to-metal joint is used without a gasket.

The "American Standard" of the American Society of Mechanical Engineers, effective January 1, 1914,* for the various flange dimensions and bolting and the standard flanges, valves and fittings as manufactured by the Crane Company, the Lunkenheimer Company, and contemporary valve manufacturers were considered as a basis for design of equipment. It was found after laying all of the above standard connections and as many of the special and odd connections as could be collected, that certain general rules and principles of design were universal, and that for leak-sealing purposes the following classification of flanged connections could be made:

*Mechanical Engineers' Handbook, edited by Lionel S. Marks. Ed. 1, 1916, p. 815.

1. Heavy brass flanged valves and fittings from ¾ inch to 12 inches (17 sizes).

2. Extra-heavy brass flanged valves and fittings from ¾ inch to 12 inches (17 sizes).

3. Standard and low-pressure flanged valves and fittings from 1 inch to 24 inches (23 sizes).

4. Extra-heavy and medium flanged valves and extra-heavy flanged fittings from 1 inch to 18 inches (20 sizes).

Classes 1, 2 and 3 have plain-face flanges and require full gaskets.

Class 4 is subdivided into six subclasses, based on style of flange-face connection:

a. Plain-face joints.
b. Low raised-face joints.
c. High raised-face joints.
d. Tongue-and-groove joints.
e. Male and female joints.
f. Van Stone or lapped pipe joints.

The various conditions of all the possible locations of leaks in each class of joint were carefully listed and studied. The same thing was done for all the varying general conditions of working clearances due to peculiarities of piping lay-out and adjacent walls, other pipes, or similar obstructions. Bolted connections and other possible leaks were similarly investigated and classified, and by a process of combination and elimination the great number of and variety of tools and appliances that were worked out at first were cut down and simplified until the present standard set of Furmanite leak-sealing equipment was developed. The complete equipment weighs 150 pounds.

The tools and apparatus are accurately and carefully made of the grades of steel most suitable for the purpose, and all parts subject to wear are hardened. With ordinary care they will last indefinitely.

The Furmanite Corporation has recently published a book, entitled "Furmanite: Its Uses and Advantages," a copy of which is included with each set of Furmanite leak-sealing equipment. This book is a complete treatise on the subject of scientific leak sealing by

the Furmanite method, and is profusely illustrated. All of the various kinds of leaks are treated, and full detailed instructions are given for the sealing operation required in each case. Everyone interested in plant maintenance where gases or fluids are confined under pressure, or used to transmit power, should have a copy of this book.

Naturally the most important part of the operation is the set-up or application of the tools and appliances. There are 12 different ways in which equipment parts may be applied to leaks. It might be well to explain here that any one set-up requires only from five to ten pieces of equipment assembled on the joint or leaking member for the complete injection operation. The pieces used are determined by the size, kind, and construction of the leaking joint or leaking member and the set-up used is determined by the kind of leak, the class of the flanged connection (if the leak be in a flanged joint), whether the joint has a full gasket or a ring gasket, and the location of the leak in respect to the space between it and the adjacent pipe, walls, or machinery.

Fig. 1 shows a typical set-up for treating a leak in a flange, and Fig. 2 shows a set-up for stopping a leak through a blow-hole or a cracked casting.

Leaks in general, as far as Furmanite leak sealing is concerned, may be divided into the following classes:

1. Leaks in plain-face flanged joints with a full gasket approximately flush with the outside edge of the joint, when the leak passes through a bolt hole.

2. Same as class 1, when the leak is between two bolts.

3. Leaks in ring-gasketed flanged joints, when the gasket is not pierced by the flange bolts.

4. Leaks in valves, fittings, flanges and similar castings through blow-holes, sand holes, porous spots, shrinkage cracks, etc.

Classes 1 and 2 may be sealed with any of 10 different kinds of set-up, and class 3 with six different kinds, giving a very wide range of equipment application to meet the most difficult and unusual leak conditions in flanged joints. Leaks in class 4 are sealed with either of two kinds of set-up, as the many different possible applications of equipment are not necessary for blow-holes, etc.

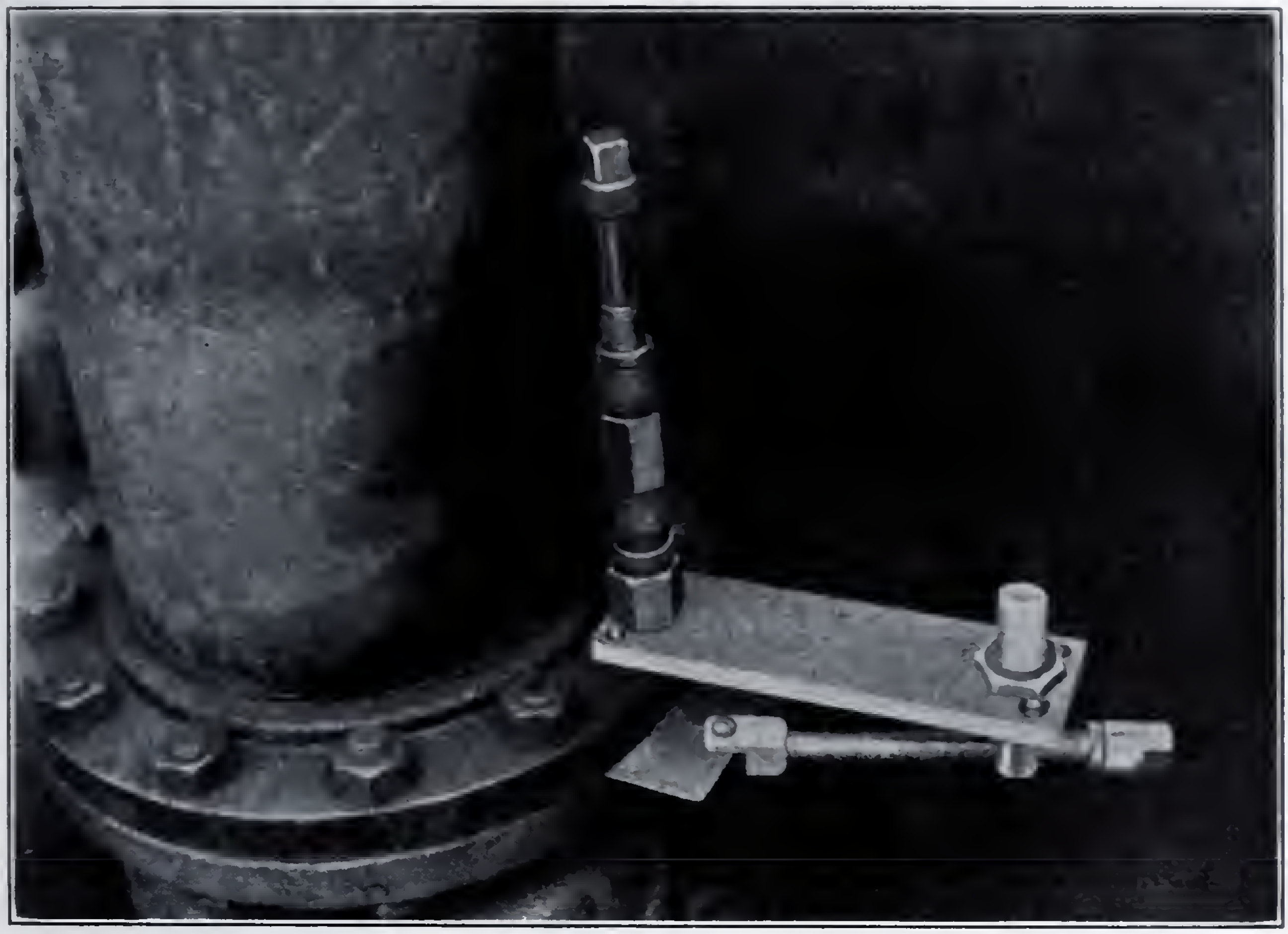

Fig. 1. Set-Up for Leak in Flange.

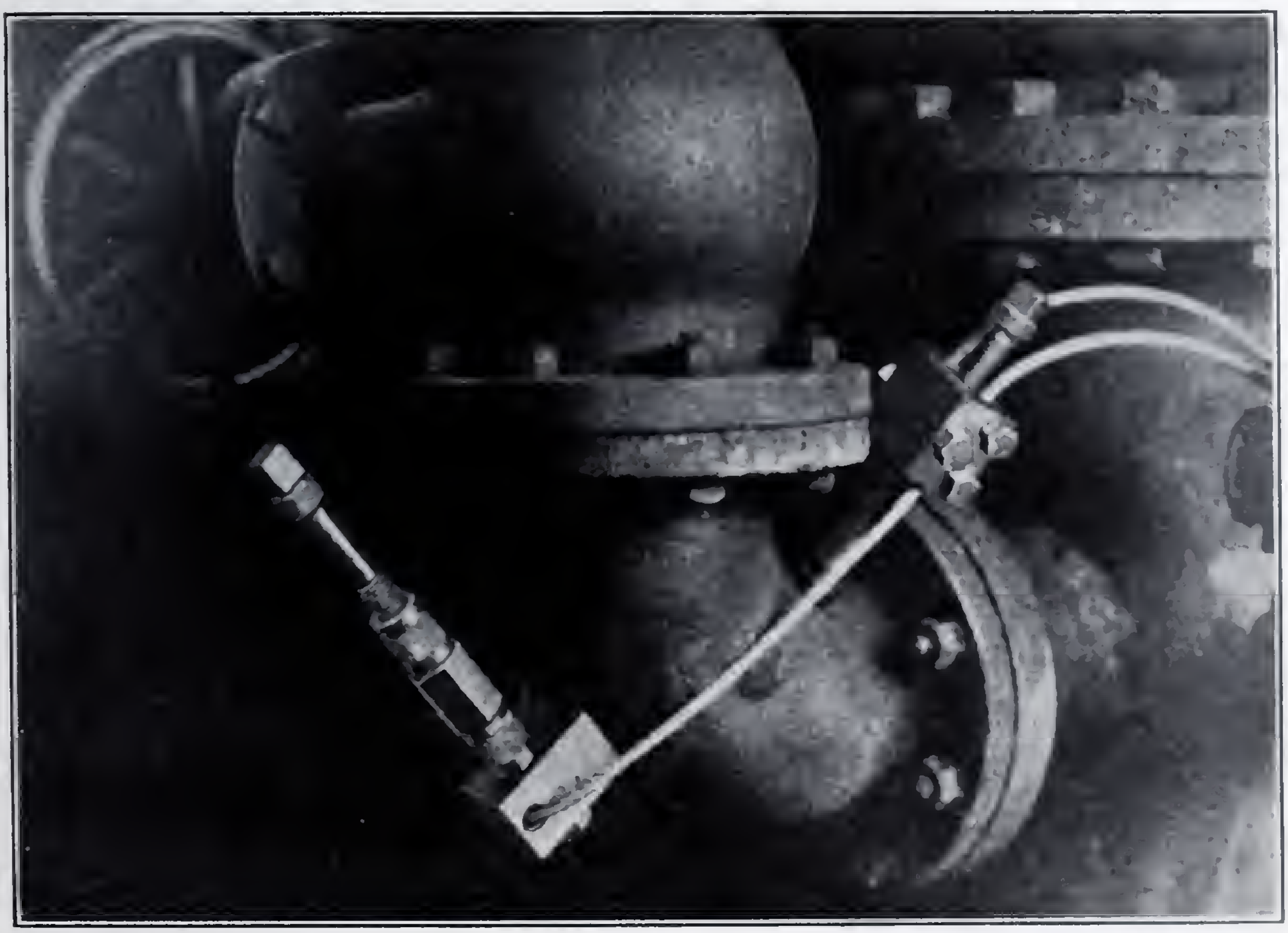

Fig. 2. Set-Up for Blow-Hole or Cracked Casting.

By means of the various kinds of set-up the compound is forced into the leak through several different channels. In leaks included in classes 1 and 2 it may be injected into the joint through a bolt hole or by direct connection with the discharge end of the leak orifice. When the compound is injected through a bolt hole the original flange bolt may be used as an anchorage for the set-up and the clearance between the bolt and the bolt hole serve as a channel for the Furmanite. If the joint is secured with "body bound" or fitted bolts a special grooved bolt is substituted for the regular flange bolt. In leaks of class 3 the sealing compound is always injected through a bolt hole, except in very unusual cases requiring unusual methods of operation. Leaks of class 4 are always sealed by direct injection into the discharge end of the leak aperture.

After the equipment is assembled on the joint or other leaking member a Furmanite cartridge is inserted in the gun and forced into the leak. If the leak is in a steam joint the heat from the steam will first melt the cartridge and then vulcanize it after it has been injected into the leak. If the leak is in a water, compressed-air, oil, gas, or similar cold fluid line or container, external heat must be applied to the equipment and leaking joint to melt the cartridge and then vulcanize it. In the case of non-inflammable fluids, such as water and compressed air, this heat may be applied with a gasoline blow-torch, steam-hose jet, or some other suitable heating apparatus. In the case of oil, gas, and other inflammable fluids the heat should be applied with a steam hose to guard against ignition.

As soon as the compound becomes soft it is forced into the leak by screwing down on the gun plunger with a ratchet wrench. In both steam joints, and cold joints that have to be heated, vulcanization will take place in from five to fifteen minutes. The equipment must be left in place until vulcanization hardens the compound, from five to fifteen minutes after the escape of steam, water, or other fluid is closed off, when all parts of the equipment are removed from the joint or leaking member.

Furmanite makes a permanent repair. The leaks in test joints under 160 pounds steam pressure sealed two years ago are still tight and dry and show no signs of breaking out again, and the pressure has not been off since the leaks were sealed. Leaks that were sealed in steam, compressed-air, and water lines at the same time are also tight.

Since the compound and equipment have been available for use by operators and manufacturers, a number of the largest concerns in the United States have adopted Furmanite, and the performance of the sealing compound and sealing equipment under actual operating conditions proves that Furmanite sealing makes a permanent seal.

Furmanite has a very important use in the sealing of turbine casings. It is injected into the groove under high pressure, and can be forced as far as 15 feet in a 3/8-inch groove. It fills the groove completely with no open or porous spots in the compound, and, due to its semi-fluid condition and high injection pressure, the density of the vulcanized compound is the same at all points in the groove around the entire turbine. The adhesive qualities of the vulcanized compound make it adhere firmly to all sides of the groove and minimize the chances of a leak breaking through. Since the sealing medium is a packing compound, and not a cement, there is no danger of cracking, crumbling or porosity taking place after the casing is sealed, as a result of the vibration, temperature changes, and other effects of turbine operation.

Furmanite is particularly advantageous in resealing turbine casings after they have been in operation, and have been opened up, or have started leaking through the metallic sealing compounds that may have been used. In most cases the leak may be sealed locally with Furmanite without opening the casing. In a casing that has been in use and is opened for resealing or other repairs, frequently the metal-to-metal surfaces of the joint are worn or eroded, and do not make the proper contact. If the casing be resealed with Furmanite the minute openings are filled and tightly sealed. The smallest steam "weeps" through minute cracks between the casings are effectively and permanently sealed.

The method has a number of economic advantages over the old practice of repairing joints by shutting off the pressure, closing down operations, unbolting and taking the joint apart and installing a new gasket. When a plant is equipped with Furmanite apparatus there is invariably a considerable saving in steam, water, compressed air, etc. The reason for this saving is quite simple. Leaks are sealed as soon as they are discovered. The size of the leak, its location and the power line or unit in which it has broken out do not affect the operation. A big leak is as easy to seal as a small one.

Even small leaks cost a surprising amount of money in terms of wasted coal, water, etc. A single steam leak through an opening 1/8 inch in diameter at 200 pounds pressure discharges 135 pounds of evaporated water an hour and uses up 15 pounds of coal every hour. The cost of coal alone for this small leak, buying coal at $5 a ton, is $24.10 a month or $289.20 a year.

Leaking joints are a menace to the personal safety of the employees. In power-plants, and particularly on shipboard, men are frequently scalded by steam from leaking joints. They may accidentally get too close to a large leak, or have to work in close proximity to the leak in the performance of their duties. High-pressure steam leaks are particularly dangerous, because when the steam is dry they are practically invisible. Even a small leak is dangerous, because it may suddenly let go and blow live steam all over the place. A sudden big blow-out in a steam or compressed-air line may also cause a terrific explosion that will damage the installation, if not completely wreck it. For these two reasons, alone, leaks should never be neglected when they may be sealed.

The labor cost of sealing a leak with Furmanite is very small in comparison with the labor cost of breaking the joint and installing a new gasket. As an example of comparative costs, a leak in a large pipe-line that requires cutting off the pressure from three to twelve hours, depending on the location and size of the joint, will cost from $10 to $50 or more in actual labor to take apart the joints and put in new gaskets. This same leak can be sealed with Furmanite in from 15 to 45 minutes by one mechanic with a few cents worth of compound. The size of the joint does not affect the labor of sealing leaks with Furmanite. Under equal conditions of accessibility to the workman, a leak in a 24-inch flanged joint is no more difficult to seal than a leak in a two-inch joint, because it is strictly a local operation performed on the joint at the leak and does not affect any other part of the leaking joint itself or any part of the complete line and pressure unit.

There is another very important reason why the strictly local leak-sealing operation is preferable to any other method of repairing the leaking joints in steam pipe-lines. When one or more leaks are repaired by installing a new gasket, the line cools off rapidly when the steam is cut off. This causes the whole pipe-line to contract or

shorten. After the gasket is installed and the flange closed, turning the steam pressure on again causes the whole line to expand or lengthen to its original position. This alternate cooling and heating throws a great strain on all of the other joints that were not leaking and were perfectly tight and satisfactory. This frequently breaks the gaskets loose in some of these tight joints, and after the first leaks are repaired fresh leaks appear as soon as the steam is turned on.

Very often when a joint is opened up for repairs it is found that the escaping steam or water has cut a groove or channel into the metal faces of the flanges, and, in old installations that have been in service for a number of years, the flange faces are apt to be rusted and eaten so that they no longer match properly. It is always very hard to make a good tight joint under such conditions, and very often it is necessary to take the valve, fitting, or cylinder head to the machine-shop and machine the damaged surfaces in order to obtain smooth flange faces that will grip the new gasket properly and make up a tight joint. Leaks in joints with grooved, cut, rusted, or eroded flanges are just as easy to seal with Furmanite as leaks in joints with flanges having perfectly matched smooth faces. The semi-fluid Furmanite is forced into every irregularity and fills the opening completely, making a "molded" gasket that is absolutely pressure tight.

When the Furmanite method of sealing leaks is adopted, the operating and maintenance engineers are able to plan and schedule their leak-sealing repair operations to fit in with their other routine repair work; whereas, when using old methods of caring for leaking joints, the time for making the repairs must be regulated to suit plant-operating conditions. The repair must be made when the line can best be shut down, unless the leak is so bad that a shut-down is compulsory. This usually calls for rush overtime work with its increased costs and the general inefficiency that goes with most hurried emergency repairs when men are crowded on a job to get it done in the quickest possible time.

Most of the plants using Furmanite have adopted a regular inspection of machinery and piping for leaks. The locations of the leaks are noted and the repair men seal them as a part of their regular routine work.

Furmanite compound, on account of the small quantity necessary to seal an average leak, is quite inexpensive. The actual cost of the

compound for sealing one leak usually varies from five cents to twenty cents, according to the size of the leak. This is usually only a small percentage of the cost of the material used in making a new gasket when repairing the leaking joint by the old method. Once the equipment is purchased and put into service there is nothing else to buy except the small amount of compound that is required. The tools and appliances will last for years without repairs or replacements if they receive reasonable care, and no tools or appliances other than those included in the standard set of equipment are required. There are no bulky clamps or unsightly appliances to be left on the leaking joint, as is the case with so-called leak-stopping devices, which are in reality only mechanical fixtures to shut off or impede the flow of steam or water from the leak. Such devices do not seal the leak; they merely aim to blank off the discharge end of it. For each separate leak a complete expensive clamping arrangement is required. In the application of Furmanite, after vulcanization has taken place, all tools and devices are removed from the flange. Nothing is left except the vulcanized compound, which completely fills and permanently seals the leak. The equipment is used solely for forcing Furmanite into the leak and holding it there until it hardens.

The speaker has witnessed a leak in the ground joint between the low-pressure cylinder and high-pressure cylinder of a huge vertical steam-engine sealed with Furmanite for $4.40. Most of this money was spent in erecting staging and removing lagging around the joint. The plant engineer told me that it would cost at least $600 to dismantle the engine and machine and grind in the joint, besides the loss of the services of the machine. I have sealed leaks myself under 275 pounds steam pressure, in an eight-inch line within 10 feet of the boiler, and I have sealed a leak in a heating system under five pounds of exhaust steam. I watched two men seal a leak in a cold water pipe joint under 250 pounds water pressure, and I saw the inventor build a whole new gasket with Furmanite on the salt-water intake line to the condensers on a ship. I have talked with the chief engineer of a big power-house who has not had the pressure off a single pipe-line for repairing a leaking joint since he began using Furmanite two years ago. I wish you might all talk with him, have him escort you proudly through his plant, and let him tell you what he thinks of Furmanite.

I can find no better words in closing than those in a short paragraph in the Furmanite handbook:

"The purchaser of a set of Furmanite Leak-Sealing Equipment does not merely buy a machine or a set of special tools. He buys a service that will save him money as long as his pressure pipes and pressure containers are in operation. He purchases a protection against shutdowns and expensive repairs. The cost of this equipment is soon written off the books, often it is balanced by the direct savings made in sealing leaks during the first few days it is in operation."

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OF THE
ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA

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DESIGN OF HIGH-PRESSURE INDUSTRIAL POWER-PLANTS*

By R. S. Bayntun†

Synopsis. The author describes the new power-plant of the Chesapeake Corporation, in which steam-boilers operating at a pressure of 425 pounds pass all the steam through a turbine to generate most of the power required for driving the machinery, exhausting into the existing steam header to supply the mills with steam at the old pressure.

He shows that by this installation a saving of $136,000 per annum is effected, paying off the whole cost of the improvements in less than three years.

He discusses the broad outlines of the design of such plants, and shows the reasons for the particular items selected, and their arrangement.

Economy Obtained by Use of High Steam Pressures. The modern tendency towards the use of increasingly high steam pressures in utility plant practice, which has been so marked a feature of the development of such plants during the past decade, has its counterpart in the slower moving and more conservative industrial power-plant, and in such industries as pulp and paper, sugar, soap, and artificial silk, which use large quantities of steam for process work at various pressures, will lead to economies which are nothing short of revolutionary. In the use of such a term the author is not guilty of any overstatement; in the pioneer plant, the broad details of which he will have the honor of describing to you, the cost of electric power, already low, has been reduced 80 per cent., the present thermal cost, in B.t.u. per kilowatt-hour, being one-half of that of the best public utilities. This, of course, is due to the complete use of the exhaust steam in process work instead of rejecting the major portion of the heat to the condensers. The electric and steam power is thus almost wholly obtained as a by-product, at very high efficiency.

The whole capital cost of the plant, though loaded with much unproductive expenditure in the form of entirely new buildings, coal-

*Presented October 5, 1926. Received for publication December 6, 1926.
†Chesapeake Corporation, West Point, Va.

handling plant, etc., will be returned in less than three years, and the net saving in the cost per ton of product will be approximately equal to the average net profit available for dividends—in other words, the saving will nearly double the company's profits.

Prospects of this order can be ignored only by such industrial concerns as are so happily placed as to be independent of competition, a good fortune that is given to but few to achieve.

Special Design of Plant Essential. Admitting, then, that it is possible in a large proportion of industries to reduce the cost of power to an almost unbelievable extent, and that the effect of such an operation may result in doubling the net profit of the concern, we come to the question of method. Is it a simple matter of ordering a new power-plant to replace the old, with the sole difference that the boilers, and turbines or engines are designed for a higher pressure? Or, can such a plant be turned out to a more or less standard design, in different sizes but broadly alike, as ready-made clothes are turned out? Or, can they even follow the same general lines and bear the family resemblance to one another that may be found in the most modern public utility plants? By no means whatever. It is the author's desire to point out, in the clearest possible manner, that the design of an industrial power-plant of the new style, though the plant may be comparatively diminutive from the standpoint of the public utility man, is a matter for careful study on the ground, and individual design, so that the plant may exactly fit all the conditions.

General Lines of Design. Having set forth the importance of fitting the plant to its conditions, we may now proceed to consider the general lines along which we must proceed in order to arrive at the individual design best suited to the local conditions, and the principles which tend most to economy. What are we aiming at, and what are the factors of economy? A few words will cover the whole ground as regards the general principles of design, though application of those principles to any selected case may involve prolonged study.

In any industrial works requiring both power for driving machinery and steam for process work, the maximum economy is obtained by selecting such a steam pressure and superheat for the boiler plant as will permit all the power required to be obtained by passing all the

steam through turbines or engines which will deliver to each of the various processes the steam required, at the correct pressure and temperature. No steam must be reduced to a lower pressure without being used for power generation, and no heat must be rejected to condensers or to the atmosphere. Briefly, generate all power as a by-product, degrade no heat, and reject no heat to waste, using all exhaust in process work.

The ideal being thus defined, it remains to ascertain how best to approach this ideal in any particular case, and how to cope with fluctuations that necessarily occur both in the demand for electrical power and for steam at various pressures.

Application of General Principles to Typical Design. To this end the author proposes to describe, in more or less detail, a new power-plant designed by him for a large industrial corporation, in which the principles set forth above have been carried to what he conceives to be their practical limit for this particular case.

The old boiler plant consisted of five 300-horse-power and one 400-horse-power, stoker-fired Wickes boilers; one 300-horse-power, hand-fired Babcock & Wilcox boiler; and a 150-horse-power, horizontal, return-tubular boiler for refuse disposal. The prime movers were two turbines of 750 and 500 kilowatts, respectively, and four engines of 100 to 400 horse-power.

The products of the mill are of two kinds, which may be designated as "A" product and "B" product. The production had been increased each year until during 1925 it averaged 70 tons of "A" product and 40 tons of "B" product daily, and it was desired to provide capacity in the new plant for making 100 tons of the "A" product, and 50 of the "B" product, daily. The old plant was too small to provide such an output, and was also near the end of its useful life after 12 years of service on the basis of a 24-hour day. It would hardly pay to make a small increase of capacity, and extend on the existing lines.

The author has been to some extent a pioneer in the adoption of mixed pressure and bleeder turbines, at an early stage of their development, having made such an installation as far back as 1912, in an electric-railway power-plant, with marked success; and, long before the present interest in the adoption of high steam pressures for use in

industry was shown by the technical press and public, he took into serious consideration the installation of such a plant for very high initial and back-pressures. He went so far as to get out a scheme calling for turbines to operate at 350 pounds initial pressure, 150 degrees superheat, and 130 pounds back-pressure along lines roughly parallel with the scheme hereinafter to be described, and in 1922 got into touch with the leading turbine makers asking for estimates for a turbine to meet the above conditions. One and all declined to quote, on the grounds that there was not enough demand for such a machine to make it worth while to estimate upon, in view of the heavy development charges.

The subject was revived at intervals, and early in 1925 general interest in the advantages to be obtained by the use of high pressures, fostered by the technical press, had been roused to such a point that the view of the turbine makers was changed, and it was found possible to get quotations for suitable machines from several of the leading manufacturers. It was therefore decided to get out a complete design for a new power-plant, having it in view to obtain the maximum possible efficiency by pushing the use of the most modern methods to the utmost limit consistent with reliability and economy of capital expenditure.

The main lines of the scheme were to install sufficient new boiler plant to deal with the whole load of the mill, scrapping all the old boilers with the exception of that used for refuse disposal, and to rearrange and partly renew the prime movers. A new power-plant building, with coal- and ash-handling plant, was included in the scheme. The object of the investigation was to determine whether the economies which could be effected would justify the capital expenditure.

It may be desirable here to revert to the principles to be followed in the design of a plant of this type. The author has already pointed out the necessity for designing the plant closely to fit the conditions, the governing factors being, on one hand, the average demand for medium and low pressure steam, and, on the other, the electrical power required.

Careful research is necessary to ascertain the lowest pressure it is possible to select for satisfactory operation of that portion of the plant which it is proposed to retain, and the amount of superheat

which can safely be allowed in the supply must also be settled. The Rankine efficiency which can reasonably be anticipated for the high-pressure turbine must be determined, and with all these factors in view a series of calculations should be made to determine the power available from the steam while being reduced from the various high and medium pressures and superheats to the selected exhaust pressures, and the condition of the steam at exhaust. In the present case a Rankine efficiency of 57 per cent. was assumed, which was afterwards found to be closely in accordance with that offered by the turbine makers for the actual machines, and calculations were made for pressures between 275 and 550 pounds by steps of 25 pounds, and for superheats of 50 to 200 degrees by steps of 50 degrees.

It was found that for the average steam and electrical demands which would exist in the new plant after the extensions in hand, and for the increased production, the best steam conditions were 425 pounds pressure and 100 degrees superheat; and that, assuming such conditions, an almost perfect heat balance for the entire plant could be obtained during average running, and maintained over a reasonably wide deviation from the normal, while at the same time provision could be made to cope with all emergencies and unusual conditions.

Main Outlines of Design. For supplying both medium-pressure steam and electrical power in widely varying quantities, it is essential, if such a scheme is to operate satisfactorily, that one of three main lines of design should be followed:

1. A steam accumulator may be installed, to take care of the fluctuations. This is expensive, cumbrous and essentially inefficient from the thermodynamic point of view, and is unnecessary, as there are better alternatives. With very large and rapid fluctuations such an installation may be justified, but the time element is the controlling factor.

2. Use may be made of a bleeder turbine large enough to supply all the power required, the requisite amounts of steam being bled off at the various pressures as needed. At first sight this method has some attractive features, especially as regards simplicity of control, but it was discarded by the author for the scheme set forth below. In the first place, a bleeder turbine is essentially a compromise in design, and either the high or the low pressure stages must suffer.

Moreover, there is a decided difficulty in taking off steam at a pressure that is at all high in comparison with the initial pressure. The machines of this type offered by the makers would have given an appreciably lower plant efficiency than the combination of straight exhaust turbine and medium-pressure bleeder turbine; also, the capital expenditure would have been higher, assuming the same capacity and stand-by plant.

However, the chief factor that decided the choice was the question of emergency running in the event of repairs being necessary to the high-pressure end. If the bleeder turbine was out of commission the whole mill would be down; whereas, in the third scheme, with the high-pressure exhaust turbine out of service (which should seldom be the case owing to its simplicity of design) the two 750-kilowatt, medium-pressure units included in the design would keep the mill going on 130-pound steam supplied by the boilers, through the reducing-valves or by operating at reduced pressure.

3. The third scheme is to employ a turbine or turbines with high back-pressure, taking all the steam generated by the high-pressure boilers and exhausting into the medium-pressure steam header at the minimum necessary pressure, operating in parallel on the electrical side with a medium-pressure turbine or turbines supplied from the high-pressure exhaust. The governing of the high-pressure units must be directly controlled by the pressure in the medium-pressure header, the ordinary speed governor being held in reserve, and never coming into operation under normal conditions.

This system is automatically self balancing for all ordinary variations either in the demand for medium- or low-pressure steam or for electrical power, the load shifting from one turbine to the other as required; thus, consider the case where, the electrical load remaining constant, there occurs an increase in the demand for medium-pressure steam. The pressure in the 130-pound line will immediately start to drop, whereupon the governor of the high-pressure turbine will open up and admit more high-pressure steam. This will result in an increased load being taken by this set, and this will, in turn, relieve the low-pressure turbine of a portion of its load, setting free the 130-pound steam it was previously taking to assist in supplying the increased demand. Correspondingly, any alteration in the electrical load will be automatically cared for, and so the whole sys-

tem will itself take care of normal fluctuations, and only very unusual conditions have to be met by hand control or the use of steam through the reducing-valves installed for such emergencies.

A necessary feature of this scheme is that the two turbines must not be fully loaded, which makes it desirable that they should be designed to give as flat a water-rate curve as possible. This partial loading of the turbines, and consequent increase of the capital cost for a given desired capacity, however, apply also to the scheme employing bleeder turbines.

For the purposes of the particular plant under consideration, this system offered considerable advantage, and it was adopted.

The principles governing the selection having been thus considered, it was next necessary to determine the lines along which to design the boiler plant.

Having decided to install high-pressure boilers, it became necessary to take steps to insure perfectly pure feed-water, for, with such pressures, priming dangers are greatly increased, owing to the smaller drums of such boilers, and to the greater danger incurred should priming actually occur. A further point to be taken into consideration was the highly alkaline nature of the make-up water, which is from artesian wells and contains from 18 to 21 grains of equivalent sodium bicarbonate per gallon. Again, it had to be remembered that it was proposed to run the boilers in certain circumstances at high ratings. Great trouble had always been experienced in the old plant owing to priming, sounding a note of warning which it would have been fatal to disregard.

The alkaline nature of the feed-water makes suitable treatment a matter of some difficulty, and, while it might be possible to find a number of systems which would more or less offer a remedy, it was felt that the only reliable method of getting perfectly pure water for the boilers was by the employment of evaporators for the whole of the make-up.

This at once raised a serious problem of economy. The proportion of make-up is very high, averaging 20-25 per cent., on account of the use of steam in process work, and it became essential to find a method which would involve the minimum of thermal loss coupled with the minimum degradation of heat.

Inquiries from two leading manufacturers of such apparatus

evoked nothing better than in one case the suggested use of exhaust steam for the evaporators, and in the other case the installation of a single-effect evaporator taking steam from the 425-pound line, and exhausting into the medium-pressure header at 130 pounds. The first plan involved the loss of a large amount of heat which could be profitably employed elsewhere without rejection of heat to the condenser. The other plan, while subject to little thermal loss, did involve a serious degradation of heat—a loss of availability of heat-units which were required to give power.

The failure of the evaporator makers to bring forward any suitable scheme left it up to the author, and he finally evolved a plan whereby losses were reduced to a minimum, and the evaporator plant, instead of being a source of loss, was put in the position of returning considerable revenue for the capital expended. The plan was, briefly, to install a three-effect evaporator taking steam from the 130-pound line, which had already done work in the high-pressure turbine, and condense the vapors from the third effect with the boiler feed-water, thus recovering all the heat-units, and carrying them back to the boilers, and also permitting about 160 kilowatts of electrical power to be extracted from the steam on its passage through the high-pressure turbines. The number of effects necessary in the evaporator is determined by the percentage of make-up and the temperature of boiler feed-water available.

It was found that the feed-water would leave the evaporator high-heat-level condenser at about 260 degrees, and a further improvement in the feed system was made by the addition of a stage heater, taking steam from the 130-pound header, which would raise the feed temperature to 350 degrees and allow of the generation of a further 70 kilowatts of electrical power from the steam necessary for the purpose. This alone would result in an economy of about two per cent. of the coal bill at a trifling cost.

The question of pure feed being thus satisfactorily settled, the next problem to be faced was that of the extraction and utilization of all possible heat from the flue-gases. Economizers were regarded with disfavor from the first, since one of the points aimed at was to have as small an amount of piping and apparatus as possible under the high pressure, and they were rendered impossible by the arrangement of the evaporator plant. This obviously called for air preheating,

and to obtain the greatest efficiency and turn the gases out to the stack at a reasonably low figure (260 degrees was the temperature finally arranged) it was decided to install air preheaters of such a size as would deliver the air to the furnaces at 400-450 degrees.

This is considerably higher than most installations of the kind are designed for, but the trend of practice during the past year or two has been in the direction of higher temperatures, and the author has no doubt that such will be common within the next two years. However, the decision was not arrived at until very careful investigation of existing plants had been made, and the working conditions in the new plant brought into consideration. The design of the combustion chamber and the arrangement of the baffles were specially considered with the high temperature of the air in view, and it was decided that whatever type of boiler should ultimately be selected, the baffling should be such that the whole length of the lower rows of tubes should be exposed to the direct radiation from the fires, as in the so-called "Alert" type of baffling in the Babcock & Wilcox boilers, and this, combined with the moderate ratings at which the boilers were normally to operate, would, in the author's opinion, largely counterbalance the increase in furnace temperature due to the preheated air. Further precautions were to be taken in the shape of ventilated side walls to a suitable height above the fire zone.

Description of the New Plant. The building is conveniently situated at the southeast corner of the mill, and is of steel-frame and hollow-tile construction, stucco covered from the firing floor up, this floor being placed 12 feet above ground level; the basement is used to allow of space for ash hoppers of such capacity as will permit the ashes formed through the night to remain till the next day, to be removed by the two men who handle all the coal and the ashes from both shifts. Two men thus replace nine under the old system. The evaporators, feed-pumps and other auxiliaries are also placed in the basement. The construction below the firing-floor level is of reinforced concrete throughout.

There are installed three 494-horse-power Walsh & Weidner boilers operating at 425 pounds steam pressure, with Foster superheaters giving 100 degrees superheat. The installation includes Westinghouse five-retort, 18-tuyere, underfeed stokers designed to burn

coal of 13,750 B.t.u. and 10 per cent. ash, and permitting of 300 per cent. rating on the boilers, but it is proposed that the normal rate of operation shall be only 200 per cent. for maximum economy and to minimize trouble with refractories.

The air preheaters are of the Ljungstrom rotary pattern, and they have to their credit the excellent performance of supplying air to the boilers at 400 degrees while passing the gases to the stack at the low figure of 260 degrees. The forced and induced draft fans are integral with the heater, and are mounted on the same shaft and driven by a 100-horse-power, General Electric, slip-ring motor, with rheostat control. The air preheaters are installed on the top of the boilers instead of being in the more usual position at the back, and the whole of the top of the boiler room—which is distinct from, and higher than, the turbine room—forms a closed box, so to speak, whence the fans draw their air. The consumption of air is such that at normal loads the whole of the air in the boiler room is drawn through the fans in five minutes, and thus there is a continuous and ample circulation of air from the turbine room, taking the hot air discharged from the generators, to the lower parts of the boiler room, thence up to and through the preheaters, carrying with it the hot air from the boiler settings, and effecting a marked regenerative action, with corresponding economy. The possibility of recovering most of the heat lost by conduction and radiation from the settings has been taken advantage of by the use of hollow, ventilated, side walls; this should, by its cooling effect on the furnace linings, improve the life of the refractories, and is diametrically opposed to the more usual practice of placing special heat-insulating bricks to keep the heat in.

Diamond "Valv-in-Head" soot blowers are installed, taking steam from the 130-pound line; this steam also has already done work in the high-pressure turbine.

Bailey boiler meters, pyrometers, and draft-gages are fitted to each boiler, and a check is afforded by a Brown electrical CO_2 recorder, which can be switched on to any boiler. Flow meters are placed in the principal steam lines for the correct apportionment of the costs.

Hagan control is installed to regulate the fan speeds according to the steam pressure, and to maintain a suitable draft over the fires.

A three-effect evaporator plant, of the high-heat-level type as set forth elsewhere, was made by the Griscom-Russell Company, and as an emergency supply, acid-treated water will be fed to the boilers, the treatment being effected by a Cochrane water treatment unit.

The boiler feed-pumps, two in number, are by the A. S. Cameron Company, and are five-stage, centrifugal pumps of very heavy and rigid construction. Each is capable of delivering 240 gallons a minute against a head of 1100 feet. They are arranged for dual drive, normally by electric motor, the work being automatically taken over, in the event of any failure, by a Westinghouse steam-turbine supplied from the 130-pound line.

Copes tension-type, feed-water regulators with pump governors are installed, and the feed range is run in a modified ring system, for security of supply. The piping is of very pure iron, to minimize corrosion. It was supplied and erected by the Pittsburgh Piping and Equipment Company, who also installed the high-pressure steam lines, these being jointed throughout with "Sargol" welded flanges, except that the valves are left free, for easy removal in case of necessity. The evaporator piping system for steam and water was supplied and erected by the Grinnell Company, and the remainder of the piping by the construction staff of the mill.

The coal- and ash-handling equipment, constructed by the R. H. Beaumont Company, is of simple design but calculated to give a maximum reliability of supply with a minimum of labor cost. It consists of a track hopper and automatic feeder leading to a double roll crusher and a chain conveyor, taking the coal up to a 150-ton, circular, steel-plate bunker, placed outside the boiler house. A traveling weigh larry is used to convey the coal to the boilers. Considerable saving in capital cost was effected by the adoption of this form of storage over the more usual method of placing an overhead bunker in the boiler house. Ground storage is used to provide a supplementary supply of coal.

Water storage is provided by three 18,000-gallon circular tanks, placed on an elevated concrete structure adjacent to the coal-bunker, and these are used respectively for condensate, acid-treated water, and raw water.

The buildings and foundations, with the stacks, flues, air-ducts and boiler settings, were designed and constructed by the Rust Engi-

neering Company, which also provided the labor for the erection of the plant.

In order to provide for exceptional conditions, when the supply of 130-pound steam from the high-pressure turbine, owing to a temporary falling off in the demand for electrical power, or an abnormal demand for low-pressure steam, should be insufficient, a complete reducing-valve system in duplicate, with a desuperheater, has been installed. The system includes an eight-inch "Arca" reducing-valve, for normal operation, with double shut-off and an intermediate drain on both inlet and outlet to permit of overhaul while steam is in the line, in spite of possible leaky valves. This is supplemented by a six-inch Fisher reducing-valve for stand-by, with single shut-off. On the outlet a manifold with four safety-valves is installed, to protect the medium-pressure line, and from that the steam is led through a 14-inch Elliott surface-type desuperheater, water for which is provided by a Gould pump having a capacity of 12 gallons a minute, with automatic start and stop.

The turbine room has at present two turbines installed. The one high-pressure unit is a 1500-kilowatt Westinghouse high-back-pressure turbine, taking steam at 420 pounds and 100 degrees superheat, and exhausting at 130 pounds to the medium-pressure steam header. This is coupled to a 550-volt, three-phase, 60-cycle generator, running at a speed of 3600 r.p.m. At full load the water rate is 60 pounds per kilowatt-hour, and at 1000 kilowatts is 61 pounds. The other turbine set is a medium-pressure bleeder, and condensing set of 750-kilowatt capacity, taking steam at 130 pounds and 50 degrees superheat, with a water rate condensing of 17 pounds per kilowatt-hour. It has been specially designed for maximum efficiency as a bleeder unit, as it is not expected to reject more than a very small proportion of the steam to the condenser. The conditions of parallel running of these sets have already been considered.

A third set will be provided by the existing General Electric 750-kilowatt turbine, which will be moved from its present site in the old plant and re-erected in the new turbine room. This will permit of running the two 750-kilowatt sets on low pressure, in the event of the high-pressure unit being out of service, and thus of keeping the greater portion of the mill in operation.

The switchboard is by the Westinghouse Electric & Manufac-

turing Company, and provides for three generators and six feeders. A voltage regulator to control three generators has been installed. All the oil switches are located in the basement, and ample room is provided for access to all parts.

Steam and Power Demand. In preparing estimates of the varying amounts of steam required to be furnished under different conditions by the high-pressure turbine to the 130-pound header, and likewise the fluctuations in the electrical load, the method followed has been to set down the individual minimum, average, and maximum demands for steam and power for each department, and, assuming the severe condition that all the minimum demands may occur simultaneously, and that likewise all the maximum demands may come on at the same time, obtain thus the range of variation in the amount of steam to be supplied.

It would be out of place here to enter into details of the above investigation, and it is sufficient to state that it was decided to drop the 500-kilowatt turbine from the old plant, replace certain of the old engine drives by electric motors, retaining such of the engines as were required to provide exhaust steam for process work, and thus improve the heat balance to the greatest possible extent.

Having made these rearrangements, it was calculated that the demand for steam at 130-pound pressure, apart from that required for the 750-kilowatt turbine, would vary from a minimum of 44,000 pounds per hour through an average of 63,000 pounds per hour to a maximum of 78,000 pounds per hour, and that the electrical load would average 1500 kilowatts, with irregular fluctuations.

These varying demands for low-pressure steam and electric power are met by varying the proportion of load automatically between the high-pressure and the medium-pressure turbines, as shown above.

Taking the steam consumption of the 750-kilowatt turbine to range from 8000 pounds per hour minimum to 13,000 pounds per hour average and 19,000 pounds per hour maximum, we have:

Minimum demand for high-pressure steam = 44,000 + 19,000 pounds per hour = 63,000 pounds per hour.

Average demand for high-pressure steam = 63,000 + 13,000 pounds per hour = 76,000 pounds per hour.

Maximum demand for high-pressure steam = 78,000 + 8,000 pounds per hour = 86,000 pounds per hour.

This average is reduced by 4000 pounds per hour by the supply from the low-pressure trash boiler mentioned earlier, so that the net average demand on the 1500-kilowatt turbine is 72,000 pounds per hour, from which an electrical power of about 1180 kilowatts is obtained at a very high efficiency.

Savings Effected and Comparative Figures. The following calculations and comparisons are based on a standard output of 150 tons of product a day, both for the old plant and the new, it being thus assumed that the old plant would have been extended on the same lines to enable it to cope with such an output.

The guaranteed combined efficiency of the boilers, superheaters, and air preheaters, with the stokers as installed, is 85 per cent. The author has assumed as a basis of calculation a 24-hour efficiency for normal running of only 78 per cent., being desirous of avoiding all appearance of overestimating the savings to be made. At the same time the efficiency for the old conditions, being taken at 67 per cent., is certainly not on the low side, so that the net estimated improvement of from 67 to 78 per cent., in substituting the most modern equipment for the old out-of-date and overworked plant, will probably be exceeded.

On the above lines, the daily coal consumption would be 68 tons, and, allowing 32 tons for week-end running and losses, the weekly coal used would be 440 tons. The annual cost would be $108,000. Similarly, for equal production, the old plant would annually consume coal to the value of $200,000, the saving on this item being $92,000 per annum. It is estimated that a further saving of $11,000 per annum will be effected by burning a cheaper grade of fuel, as the old plant required coal of the highest possible quality, and correspondingly high price.

The repairs bill to the old boiler and stoker plant was excessive, and a moderate estimate has been made of saving 60 per cent. of the expenditure on those items, reducing it from $30,000 to $12,000 per annum—a saving of $18,000.

The staff for the old plant has been reduced by 14 men—fire-

men, ash rollers and coal passers—with a net saving of $20,000 per annum.

The costs of material, depreciation, and burden have been taken as remaining unchanged.

Comparative Costs on a Basis of 46,800 Tons Annual Output. On the above lines, the power cost for the new plant would be $163,500 per annum; whereas, for the old plant extended on existing lines it would be $300,000 per annum—a net saving of $136,500 per annum.

Capital Costs. The estimated cost of extending the old plant to cope with the desired increase of output was $80,000. The new plant has cost well under $350,000, so that the whole capital will be returned in less than three years.

Miscellaneous Figures. The following figures afford some comparisons:

Power cost per ton of product

	Dollars
Old plant, 1920	13.21
Old plant rearranged, 1925	6.95
New plant, estimated	4.05

Coal per ton of "A" product

	Pounds
1920	2110
1925	1360
New plant	734

Cost of electric power, old plant

	Cents per kilowatt-hour
1920	1.0
1925	1.11
New plant	0.19

Conclusion. The author wishes here to express his deep appreciation of, and admiration for, the enterprise and business acumen dis-

played by the President and Vice-President of the Company in adopting a scheme involving such a marked departure from established lines, and carrying with it so heavy a pecuniary risk. He is particularly grateful for their engineering ability, which enabled them to deliberate upon, and appreciate, the technical points of the proposals.

DISCUSSION

W. D. Canan:* I am sure the paper has interested all of us not only because of the detailed information which has been given us about a plant which has actually been built and is operating to-day, but also because Mr. Bayntun's scheme may be applied to any industrial plant where conditions are somewhat similar. He mentions the fact that the Rust Engineering Company was interested in the construction of this plant. In addition to the complete design and construction of the building, we handled such matters as the design of all duct work, boiler furnaces, machinery foundations, piping, etc., as well as the installation of all machinery. I may say that we are very proud indeed to have had such a large part in building a power-plant that gives promise of such great savings as Mr. Bayntun has indicated.

Before being awarded the contract for this work a great many conferences with Mr. Bayntun and other officials of his company were necessary. Our interest in this problem naturally became aroused and we decided that we would like to design a plant without reference to what Mr. Bayntun had already done. It may therefore be of interest at this time to explain in general the points of essential difference between his scheme and ours, and also give some of the economic results it was expected to obtain. Bear in mind the fact that Mr. Bayntun built the plant which he thought was best, which choice we can not disprove at this time because we did not build our plant.

The points we had in mind in the preliminary design were reliability, flexibility, and economy. After the matter of establishing a boiler pressure had been decided, the principal thing which had to be taken into account was the selection of the prime mover. Our choice fell on the bleeder type of turbine. We felt that with the bleeder type a little greater flexibility would be obtained, with perhaps not so good economy in the plant. We decided that a compound unit would be a better proposition than having two units under one casing. The two

*Rust Engineering Co., Pittsburgh.

units would be connected mechanically by means of a shaft and the generating unit placed on one end. These bleeder units we had in mind were 750 kilowatts. The size was influenced partly by the fact that he already had a 750-kilowatt unit installed which he wanted to use, and by putting in units of that size it would be much easier to add to the plant later.

Mr. Bayntun has mentioned the fact that his processes required steam at various pressures. We had in mind establishing three separate steam lines, one operating at high pressure which would take steam from the boilers at boiler pressure and superheat, and an intermediate-pressure line taking steam from the bleeder units, using this steam for various primary processes and exhausting from these processes such steam as was available for re-use into a third or low-pressure line. The pressure in this low-pressure line would be fixed by the highest pressure required by any of the secondary processes, lower pressures being supplied by reducing-valves.

Fig. 1 shows the schematic lay-out of our particular design in so far as steam distribution is concerned.

Having this particular lay-out in mind, the figures given below indicate what was to be anticipated in the actual operation. Table I shows the demand on the 150-pound or intermediate-pressure line, for the various primary processes together with the rate of bleeding from the turbines and the minimum electrical load required to bleed this quantity of steam. Table II shows the steam demand in the low-pressure line. It will be noted that a deficiency of low-pressure steam as exhausted from the primary processes was anticipated, which would have to be made up by means of a by-pass line. Table III shows the condensate returns and make-up. Table IV shows the expected boiler operation.

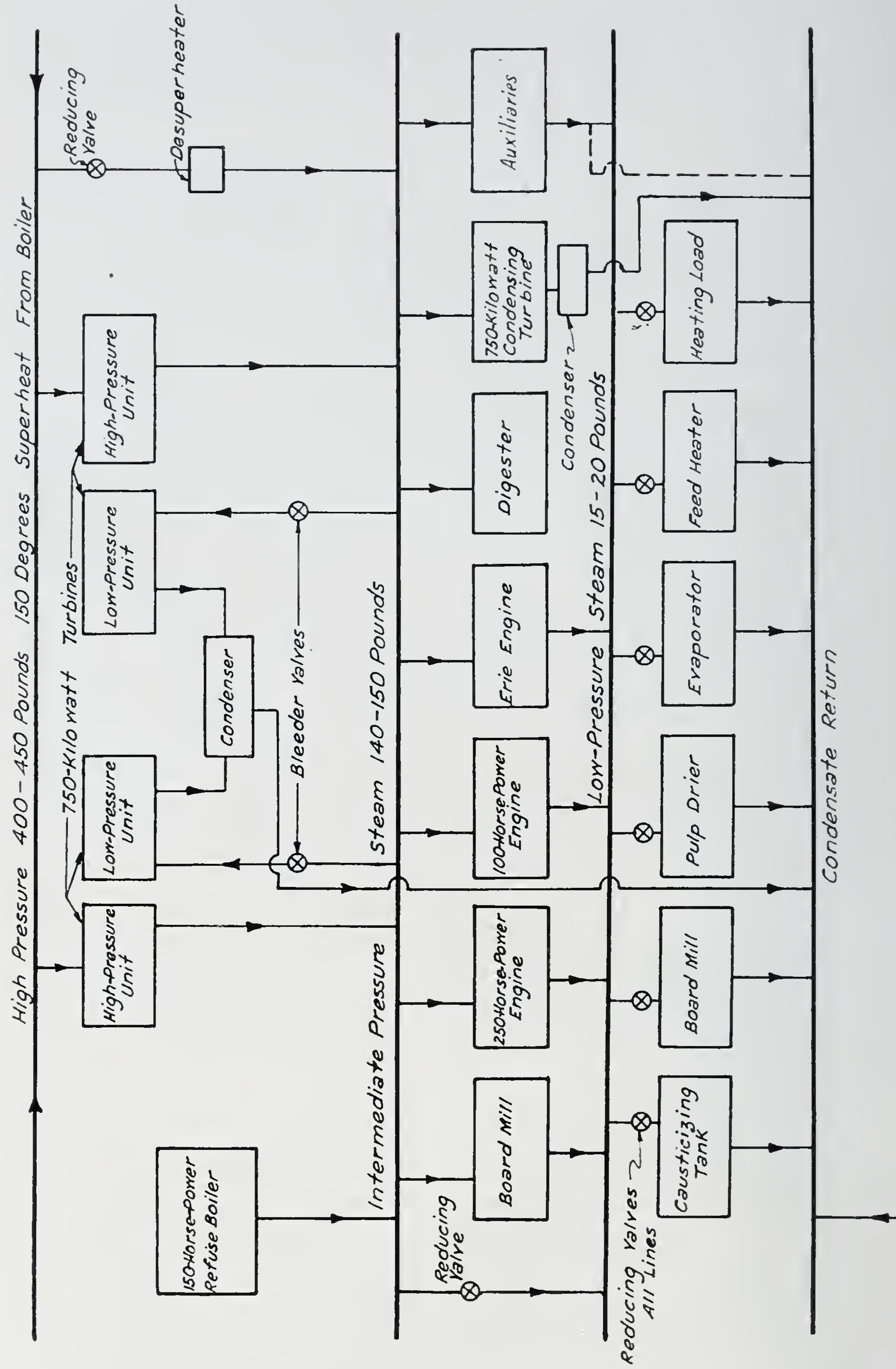

Fig. 1. Schematic Diagram of Steam Distribution, Chesapeake Corporation, West Point, Va.

TABLE I. STEAM DEMAND IN POUNDS PER HOUR AT 150 POUNDS PRESSURE

	Minimum	Average	Maximum
Miscellaneous board mill	3,000	4,000	6,000
250-horse-power engine	10,000	15,000	30,000
100-horse-power engine	6,000	6,000	6,000
Erie City engine	6,000	6,000	6,000
Digester	11,800	14,300	16,300
Auxiliaries	5,000	7,000	10,000
Total	41,800	52,300	74,300
Deficiency from 20-pound line	1,500	4,200	9,500
Total demand 150-pound line	43,300	56,500	83,800
Amount supplied by refuse boiler	4,000	4,000	4,000
Amount bled from turbines	39,300	52,500	79,800
Minimum electrical load to bleed, this amount available for use at 20 pounds (Kilowatts)	500	700	1,200
Total, less digester	30,000	38,000	58,000

TABLE II. STEAM DEMAND IN POUNDS PER HOUR AT 20 POUNDS PRESSURE

	Minimum	Average	Maximum
Causticizing tank	1,000	1,000	1,000
Board mill	10,000	15,000	30,000
Pulp drier	6,000	6,000	6,000
Evaporators	7,500	11,500	18,500
Feed-heaters	7,000	8,700	12,400
Total	31,500	42,200	67,500
Amount available	30,000	38,000	58,000
Deficiency (to be supplied through by-pass from 150-pound line)	1,500	4,200	9,500

TABLE III. CONDENSATE RETURNS AND MAKE-UP

	Minimum	Average	Maximum
Board mill	10,000	15,000	30,000
Pulp drier	6,000	6,000	6,000
Evaporators	7,500	11,500	18,500
Feed-heaters	7,000	8,700	12,400
Total	30,500	41,200	66,500
From turbine at 1200-kilowatt load	12,500	11,500	2,200
Total	43,000	52,700	68,700
Make-up	9,000	11,300	13,300
Percentage, including refuse boiler..	23	22	20

TABLE IV. ANTICIPATED BOILER OPERATION

	Minimum	Average	Maximum
Demand on boilers for 1200-kilowatt load (bleeding as above)	52,000	64,000	82,000
Boiler horse-power	1,730	2,140	2,840
Percentage rating (two 500-horse-power units)	173	214	284
Percentage rating (two 600-horse-power units)	144	178	238

There are two important points in connection with this lay-out. One of them is the amount of heat rejected to the condenser. I think we figured out at that time that our heat rejection to the condenser was six or seven per cent. Mr. Bayntun told me that his scheme gets in the neighborhood of three or four per cent. The cost of production based on 810 tons, which we used at that time, made our scheme work out to about $5 a ton. His works out $4. I do not know what ours would work out at on the larger production basis.

It is not with any idea of criticism that I offer this particular lay-out, but with the thought that it might be considered an exension of what Mr. Bayntun offered, and also to take up one of the problems he rejected. This happened to be the bleeder turbine scheme. When we started out we had in mind the use of units of this particular type,

feeling that it would possibly give us quite good flexibility and make it possible to make additions to the plant without disturbing the heat balance.

I would like to ask Mr. Bayntun a couple of questions. There was one other scheme that we did not take into account. I have been wondering if it might be possible to use non-condensing bleeders. There has been quite a bit of discussion in the papers recently, particularly on the part of the turbine builders, on the use of a non-condensing bleeder to bleed at one pressure and exhaust at another pressure above atmosphere. Has the speaker given that particular scheme any consideration in his plant?

Another thing that interested me in his paper is the governing of the 1500-kilowatt units. He states that his governing is done entirely by the demand for steam at the intermediate pressure (130 pounds). I was wondering what would happen in the case of a continuous demand for steam at the intermediate pressure and a change in the demand for electricity.

In figuring out the cost of production, does he take the overhead into account? He said he assigned the depreciation burden in the new plant the same as the overhead. That would mean to place on the old plant a valuation of $350,000. Is that considered the value of the old plant?

R. S. Bayntun: Mr. Canan has contributed a very interesting discussion and described a scheme that does not differ very much from the scheme selected. The reason why we did select my own scheme rather than the bleeder type was principally this. It is true that a bleeder-turbine station would have given easier regulation; but we felt that, first of all, a bleeder is essentially a compromise. You get a good low-pressure end or a good high-pressure end, but not as good efficiency as we actually got by having a separate high-back-pressure turbine and a separate bleeder unit. That is one item that weighed with us. A more important item was that we already had a 750-kilowatt bleeder unit, and by putting in another 750-kilowatt unit and a 1500-kilowatt, high-pressure unit we had a better combination. In a high-pressure machine you have a very simple unit. If it did go wrong it would not put the mill out of operation. We should then be able to take the two 750-kilowatt units and run them at low pres-

sure and keep the whole mill going, at reduced economy, while the high-pressure unit was being repaired. The alternative of putting in a 2000-kilowatt bleeder would have involved shutting down the mill and stopping everything if that turbine went out of commission.

As regards flexibility and ease of control, events have proved that there is nothing to that. The regulation is just as easy on the two sets in parallel as on a bleeder turbine. I had some doubt as to the system of governing which I mentioned, and regarding which Mr. Canan has asked some questions, but it is functioning very well. The load changes from one generator to the other just according to the changes in the electric demand and the steam demand. Mr. Canan asked what occurred in case of the steam demand remaining constant while the electric load varied. The electric load comes on, the two machines are running in parallel, and it starts to come on both machines equally. When it does that, the high-pressure machine, which is being governed by the demand for low-pressure steam, will not take it because the steam given to it is controlled by the governor from the low-pressure header, and the increase in the electrical demand is taken by the low-pressure unit. The reverse of that condition is when the demand for low-pressure steam varies with the electric load remaining constant. For instance, say the digesters take 15,000 pounds of steam. The pressure immediately drops slightly on the low-pressure header. As it does that, the governing valve on the high-pressure turbine opens out sufficiently to balance the increased demand for low-pressure steam and it takes over more of the load from the low-pressure turbine and relieves the steam which was previously being used to generate that portion of the load, and that helps the increased demand for low-pressure steam. That sounds complicated, but it works out quite simply and takes care of itself. In operation, you can not change by hand the distribution of load as between those two machines. The load is settled absolutely by the proportion of the steam and electric demands and you can have no hand control at all. It is all automatically accomplished. Mr. Canan's scheme is a good scheme, but we thought it was not as good as ours. The bleeder turbine is not quite so efficient and not so suitable to our conditions.

Regarding the other point, Mr. Canan wanted a low-pressure main header at the highest pressure required by any of the low-

pressure systems and to reduce from that where necessary. That is thermodynamically inefficient. The maximum pressure of these low-pressure lines would have to be 30 pounds. The amount of steam that would be required at 30 pounds is a very small proportion of the total, so most of that would have to be reduced to an average pressure of 10 pounds. Between 30 pounds and 10 pounds pressure there is a very large number of heat units involved and it would cause a considerable loss of energy which is unnecessary in view of the scheme that was adopted.

The use of non-condensing bleeders was questioned. That is the same practically as we have. Our high-pressure system is a non-condensing system. The only point is that we change the pressure from 450 to 135 pounds, and thence to the low-pressure turbine which bleeds at 10 pounds; whereas, by his scheme, it would run on one machine right down to 10 and bleed at 135. I believe the bleeder arrangement for taking the steam at that high pressure would be more expensive, but I would not like to say so, definitely.

The last question concerned the inclusion of overhead costs in the design. This paper is enlarged from the original paper I gave before the American Society of Mechanical Engineers last week in Richmond, and it was prepared in considerable hurry. I had just five days in which to get it together. Most of it was taken from a report which I made to the Directors about this scheme, on which report the scheme was accepted. These figures were prepared without consideration of overhead because I wanted to show plainly and simply how much money could be saved annually by adopting a new plant and how much it would cost to do it. These figures showed that the plant we have would cost $330,000 and it would save $136,000 a year. That seemed to be a very simple way of putting it. I could have figured the overhead charges at six per cent. and 10 per cent. depreciation and, after deducting that, could have stated the net profits, but the simplest form, considering the large proportion of saving to actual cost, was to give the actual saving and actual capital and say you will pay back your entire capital in 2¾ years. I adopted the figures of that report and inserted them in the paper. That is why overhead was not taken into account. Of course it would have been in a full consideration of the whole scheme.

C. D. Foight:* In the regulating mechanism, what would happen in case the steam demand were very large and the electric demand very small? When the electric demand is reduced in relation to the steam demand there would be a point at which the low-pressure, bleeder-type turbine would be delivering zero power. Beyond that point I would like to know what would happen.

R. S. Bayntun: That point has been allowed for by the installation. The high-pressure turbine is governed by the pressure in the low-pressure header. If there is demand for low-pressure steam beyond what the existing electric load can cover, the pressure simply drops down, because the speed governor comes into action. The pressure would drop in the high-pressure line and, when it drops from 135 to 125 pounds, the reducing-valve will come in; and when the electric load is increased or the steam demand decreased the reducing-valve cuts out automatically. That is something that may arise very seldom.

B. M. Herr:† What type of reducing-valve and desuperheater did you use on the by-pass between the high-pressure header and the intermediate-pressure header?

R. S. Bayntun: We use a system of reducing-valves in duplicate. We put on two reducing-valves of different makes, for variety, and because we wanted one cheap one and one good one. I do not know that I ought to name the cheap one. The good one is an "Arca" reducing-valve. That particular one we have with a double shut-off—two valves on the high pressure with two valves on the low pressure and a bleeder in between, so that we could overhaul it if necessary. Then we have an Elliott desuperheater which reduces the temperature to a suitable point.

F. R. Magill:‡ Do you take care of all the electrical generation required in the plant, or do you have to tie in with a commercial power-station?

R. S. Bayntun: There is no tie in because the nearest system

*Engineer, Rust Engineering Co., Pittsburgh.
†Herr-Harris Co., Pittsburgh.
‡Sales Engineer, Dingle-Clark Co., Pittsburgh.

is about 40 miles away and I think they would not be willing to run a 40-mile line for the occasional opportunities to tie in that we should afford.

F. R. MAGILL: My reason for asking this question is that we have a comparable situation in the Pittsburgh territory. A plant located in Ambridge, Pa., is installing a 750-kilowatt Terry turbo-alternator, taking steam at 400 pounds pressure and 100 degrees superheat. This is a non-condensing, bleeder unit, bleeding at 125 pounds gage and exhausting at 55 pounds gage. The plant requires more electrical energy than this unit will generate, and it will therefore operate in parallel with purchased power. The unit will be of the back-pressure control type, and the amount of energy generated will be in proportion to the demand for exhaust steam controlled by process requirements. Savings due to the use of this high-pressure unit are expected to pay for the entire boiler and turbine in less than three years; or, the savings will pay for the turbine and the extra cost of boiler plant, over the cost of boiler plant for process steam only, in about one year.

The savings possible with the use of the high-pressure units in industrial plants are enormous, and we are pleased that industrial concerns are giving more thought to this possibility and that some of them are taking advantage of the savings possible by installing high-pressure, non-condensing units where they have a use for process steam.

R. S. BAYNTUN: That is a favorite idea of mine that I want to see come to pass in the next few years. Certain industries which use enormous amounts of process steam but not very much power could and ought to put in high-pressure boilers to generate power and sell it to the utilities. There is great saving of coal to be obtained in that way. I know of one case where a soap-works uses 12 cars of coal a day. They could have obtained enough power from a plant like this to sell 15,000 to 20,000 kilowatts to the public utilities six days of the week, 24 hours a day, and build a plant which would pay interest on the investment comparable to what we are getting in our plant; and the surplus power, if sold at a price equal to the actual coal cost in the utility plant, would return somewhere around $100,000 a year.

That is going to save a great many tons of coal, and the return to the investors may be 35 per cent. on their capital, which affords a prospect too important to be neglected. What you mentioned just now is leading up to the same idea.

C. G. Thornburgh:* May I ask, in determining the cost of power, whether that is the actual cost of generating the power, and no credit is given for any of that recovery of steam used in process work?

R. S. Bayntun: The figures for cost of actual power were first of all operating figures pure and simple, because all our figures were operating figures and we wanted those for purposes of comparison.

If it were necessary we could purchase electric power; but the steam had to be generated anyway. We could not purchase process steam, and therefore the electric power was a by-product. If the opposite condition had occurred, then the process steam would have been the by-product. We realized that we had to have the steam, however it was generated, and the power we obtained was a by-product and chargeable only with the increase over the cost that would have been obtained if we generated the steam alone. Roughly I figured it as follows. It takes about five per cent. extra heat to raise steam to 425 pounds as compared with 150. That steam in passing through the high-pressure turbine loses a certain portion of heat, due to the change of heat-units into power. That power is obtained to that extent at the full efficiency—an equivalent rate of 3412 B.t.u. per kilowatt-hour. Outside of that, you have a certain loss in the generator which has to be deducted, and also radiation and other minor losses. Allowing only 75 per cent. efficiency for it makes about 4400 B.t.u. per kilowatt-hour for the steam that is bled. In addition, you generate some electric power from the steam you exhaust to the condenser, and that is the controlling factor in the cost for electric power. We figure that we reject to the condenser about four per cent. of the total steam, and that small amount is responsible for the greater portion of the cost of electric power. The combined cost is the actual cost of the electric power. Combining the two, that

*Engineer, Rust Engineering Co., Pittsburgh.

works out to approximately 7000 B.t.u. per kilowatt-hour. If we have a certain boiler capacity and we get so many thermal units from a pound of coal, and we burn a definite amount of coal with a certain boiler efficiency, we get the cost per kilowatt. Adding operating cost, wages, repairs, waits, etc., it brings the cost up to a cost of 0.19 cent per kilowatt-hour. That is how we arrived at that point.

C. D. FOIGHT: How do you expect to maintain an average overall efficiency of 84 per cent.? Do you expect to make periodic tests in which you go through the process of measuring the water accurately and analyzing the coal?

R. S. BAYNTUN: As a matter of fact, I did not expect to get quite as good an average. We are getting better boiler efficiency than I had anticipated—at present about 84 per cent. In my cost estimate I figured on getting only 78 per cent., and the overall efficiency on the old plant was 67 per cent.; but I wanted to be on the safe side. I believe that the relative figures (which are what count in the saving) will be maintained, whatever the actual figures are. We have no need for taking those particular tests frequently. We have instruments showing temperatures at different points, etc., and CO_2 recorders to check up on them, and if all those factors keep right—stack temperatures, air temperatures, CO_2, etc.—we are going to maintain efficiency.

C. G. THORNBURGH: Regarding the low-pressure steam units, you have some at 30 and some at 3. Do you bleed at various pressures?

R. S. BAYNTUN: The low-pressure bleeder turbine is used solely for one process—for evaporators at 10 to 15 pounds. The other processes are served by the original engines which do the driving. A 350-horse-power Corliss engine exhausts in the driers, which requires 5 to 30 pounds back-pressure. You can vary back-pressure in an engine more easily than you can on a turbine, and the plant was already there, so no new plant was involved. In the same way, we had other engines driving other parts of the machinery, each exhausting into its own piece of apparatus at the pressure required, so in no case

was there any degradation of heat. Each engine operates at the back-pressure that best suits its particular process.

W. W. SPRATT:* I would like to ask Mr. Bayntun a few questions:

1. Does Mr. Bayntun happen to have with him the fixed charges of the 425-pound boiler plant to permit determining the cost of steam per 1000 pounds at the boiler plant ready for the turbines? I imagine the higher first cost of the 425-pound boiler house has an appreciable effect on the cost of steam.

2. What is the fixed-charge item of the cost of power? I suppose this has been allocated on a B.t.u. division basis for the steam cost to the turbines in a manner such that process steam and power steam get their proportionate share of boiler house fixed charges.

3. What is the ratio between average daily kilowatt load and 15-minute peak-load in the mill which has been taken as an example? Most paper-mills have a high load-factor, many of them, I have observed, having a load-factor of from 85 to 90 per cent.

The subject Mr. Bayntun has selected to-night is becoming a very important one in the paper industry; in fact, it has always been an important subject, but it is only recently getting its proper attention. Paper-mills are large users of process steam, requiring three to five pounds of steam for every pound of paper dried, and larger quantities of steam for cooking of pulp, etc. The average size mill will take from 75,000 to 100,000 pounds of steam per hour; and the steam demand of the larger mills may range from 150,000 to 500,000 pounds of steam per hour, indicating the importance of modern boiler plants. By the use of moderately high boiler pressures, such as 300 to 425 pounds, practically all of the necessary power can be obtained as by-product power between the boiler pressure and the necessary process pressure. A number of plants in the last three to four years have been installed at 300 pounds, and we have seen to-night an excellent example of what is possible by going to 425 pounds pressure and 100 degrees superheat. I would judge from the discussion here to-night that Mr. Bayntun has solved his problem well. His method of solution indicates the necessity of studying each individual prob-

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lem, and it also indicates the possibilities from a well prepared solution. I believe a number of mills will follow Mr. Bayntun's example with equally attractive rewards.

R. S. BAYNTUN: You refer to the higher cost of the high-pressure plant. That is where you make a mistake. I expected to be asked that. If we had put in a low-pressure plant comparable in all ways to the high-pressure plant it would have actually cost more instead of less than the high-pressure plant. The difference would not have been very large, but it would have been unfavorable to the low-pressure plant. It would have been less economical and would have required 300 boiler horse-power extra at the start. We should have had against us the cost of boilers. The boiler in the high-pressure plant costs more per horse-power; the superheaters cost more; three regulators would have cost slightly more; the fittings and pipes would have cost considerably more; and reducing valves, superheater piping, and valves make a considerable item of cost against the high-pressure plant. But the low-pressure plant turbines would have cost more. Condensers would have been necessary in the low-pressure plant—not in the high pressure. Stokers would have been more expensive, because you would have to burn more coal. Air preheaters would have cost more; furnace blocks, furnace foundations, etc., would have been very largely against the low-pressure plant. The total cost would have been about $12,000 more for the low-pressure plant. As regards the working results—the cost of electric power very roughly would have been $64,000 a year for the low-pressure plant as against $20,200 for the high-pressure plant, making the saving for the high-pressure plant $44,000.

JOHN A. GRAHAM:* What kind of coal is used?

R. S. BAYNTUN: Crushed run-of-mine. In the old stokers we had to use the best coal we could get. Later, we will try nut and slack from the same mines. The stokers were purchased with the understanding that we should get 13,750 B.t.u. and 10 per cent. ash. At present we are getting 14,500 B.t.u. and six per cent. ash. The freight rate at present is more than the total cost of the coal. If we

*Superintendent, Buildings and Grounds, Shady Side Academy, Pittsburgh.

burn cheap coal we burn more of it and pay out in freight more than we save in coal and also have to deal with the ash difficulties.

John A. Graham: Do you find much ash carried through the stack?

R. S. Bayntun: About 10 per cent. of what we used to have.

John A. Graham: Do you find any accumulation in the preheaters?

R. S. Bayntun: None at all, so far.

AUTOMATIC CONTROL OF COMBUSTION*

By T. A. Peebles†

The combustion of fuel follows well-known chemical laws. Before the reaction can take place, certain conditions must be complied with, such as the bringing together of fuel and air and the development of a temperature at which the comparatively rapid chemical reaction, known as combustion, can take place. In order that this process may be continuous it is only necessary that, once it is started, fuel be supplied as needed and air be admitted to the burning fuel. There is no relation between continuity and efficiency of the process.

The burning of fuel has long been utilized as one of the steps in the production of power, and the chemistry of the process has been quite well understood. It is only within recent years, however, that any great progress has been made in the efficiency of combustion, and this has been due to the attention given to the underlying principles by those interested in combustion.

A suitable furnace was not available until a few years ago. The idea prevailed that the closer the fire was brought to the heat-absorbing surfaces the more effective would be the whole operation. Later it was recognized that combustion of fuel was not complete in the fuel bed and that a certain amount of space was required between the fuel bed and the heat-absorbing surfaces to allow for the complete mixing and burning of that part of the fuel leaving the fuel bed in a gaseous state. Gradually furnace designs have been improved until to-day the subject is thoroughly understood, and the results which can be attained are surprisingly close to those theoretically possible. For the best results, even in a suitable furnace, the fuel and air must be supplied in definite proportions which differ somewhat for different types of fuels and furnaces, but which can easily be determined for any given condition.

Since the burning of fuel is only one step in the production and utilization of heat or power, the rate at which this combustion must be carried on is determined by the demand for the products (such as electric power, steam, or hot water) which ultimately result from the combustion of fuel. It is, therefore, necessary that the rate of combustion be varied according to the need, and it is not possible to pro-

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vide some means for supplying constant quantities of fuel and air and then allow the combustion process to proceed at a fixed rate.

The combustion processes in which we are most interested are those relating to the burning of fuel under steam-boilers, and further discussion will be confined to this particular field.

When several boilers are put into operation to carry a given load, it is assumed that there is some good reason for using this number of boilers. The engineer in charge of the plant knows from experience and tests that the boilers give different results at different rates of operation. There is a range of capacity over which the combined efficiency of combustion and heat absorption by the boilers is the highest, and the number of boilers selected for operation will most economically carry the expected load. Since the load is never uniform, it is necessary that variations in the rate of combustion take place from time to time, and this calls for adjustments in the rate of fuel and air supply. In the case of steam-boilers, any lack of balance between heat absorbed by the boilers and steam withdrawn from them results in a change of steam pressure, and there is available a means by which the operator is guided in varying the rate of fuel and air supply. Means are always provided by which an operator may adjust the rate of both the fuel and air supply to the furnaces under his control, and these adjustments are made in accordance with variations in the pressure of steam generated. These adjustments can be made manually and, until recent years, were so made in the greater number of plants. During the last few years, however, engineers have come to realize that automatic devices will do this work much more effectively than it can be done manually, and apparatus for automatic control of combustion has been installed in a great many plants.

Since the careful operator puts into service the number of boilers which will operate at or near their point of most efficient rating in order to carry the expected load, it follows that the boilers should all operate at the same rating if the desired result is to be secured. If two boilers, which give the best result at 150 per cent. rating, were put on the line to carry a given load which could be carried when both were operating at 150 per cent. rating, good operating results would be expected. These results would not be realized, however, if due to careless operation one of the boilers was allowed to operate at 100 per cent. rating and the other at 200 per cent. rating. It is nec-

essary that they operate at the same rating, and this is one thing that combustion-control equipment can accomplish more effectively than hand adjustment.

The rate of combustion is determined by the rate of air supply to a furnace rather than by the rate of fuel supply. In any furnace burning a solid fuel with the grate surface properly covered, the momentary rate of combustion varies with the air supply and is not dependent upon the rate of fuel supply. It is, therefore, necessary that equal quantities of air be supplied to all furnaces, and this must be accomplished regardless of the varying resistances of individual fuel beds. Combustion-control equipment, therefore, must automatically supply equal quantities of air to different furnaces regardless of fuel-bed resistances, if equal ratings are to be maintained on all boilers. There are various ways in which this can be accomplished, and the purchaser of such equipment may select from these schemes the one which in his judgment best suits his conditions.

In order to reduce air infiltration, and to prevent gases blowing out from the furnaces, it is desirable that a pressure slightly below that of the atmosphere be maintained at the top of the furnace. This is easily accomplished by automatic means in any one of several ways, and the purchaser in this case also has a choice as to which method he will employ.

While it is not necessary that the momentary rate of fuel supply shall equal the rate of combustion, it is necessary that over a longer period of time the fuel be proportioned to the load. It is an easy matter to proportion the stoker speed to the load or to the rate of air supply, but this does not always insure the right rate of fuel supply. Differences in the heating value, size, and moisture content of the coal all affect the rate at which a stoker must operate to deliver a given amount of fuel value to the furnace, and it is not so easy to correct for all these variables by automatic means. It is usually much simpler to provide a convenient means for hand adjustment of stoker speeds in addition to the automatic control. The automatic control will then vary the stoker speed in accordance with the load, and from time to time a slight manual adjustment can be made by the operator as an inspection of the fuel bed may indicate its desirability.

Automatic control equipment is desirable in every plant because it relieves the fireman of the necessity for making adjustments to meet

variations in load and leaves him free to devote practically undivided attention to the maintenance of the best fuel-bed conditions. The adjustments of fuel and air supply to meet varying loads are made simultaneously on all boilers and in proportion to the extent to which the load has changed. This can not be done by the operator with the same degree of uniformity and accuracy. It is, therefore, to be expected that the use of control equipment will improve operating conditions without considering the better attention which the operator is able to give to fuel-bed conditions when relieved of the work of making fuel and air adjustments in accordance with load variations.

Automatic control is especially valuable in plants where boilers are operated at a capacity far below their maximum. The load conditions in some plants require that during long periods of time boilers be operated well below their maximum rating in order to meet sudden increases in load. In such cases there is a tendency for the fireman to operate with the fires too light for best results with an unnecessary amount of excess air, with the result that the efficiency is far below that which should be secured. Automatic control has made some rather surprising fuel savings in just such cases.

In the burning of powdered coal the disturbing effect of fuel-bed conditions is done away with, and for this reason the control is simplified. On the other hand, however, there is no storage of fuel in the furnace and the momentary rate of fuel and air supply must be correct if efficient results are to be secured. For this reason it is essential that some means be provided for controlling the fuel and air supply in proportion to the load and maintaining the proper relations between the two. This can be accomplished by means of automatic equipment, but there are at present so many different methods of preparing and introducing powdered coal to furnaces, with a variety of arrangements for admitting the air for combustion, that it is impossible to outline in advance any arrangement which will suit the different combinations of fuel and air supply.

It should always be kept in mind that equipment for combustion control is not intended to replace a capable fireman. There are some engineers who visualize a control panel from which one operator controls the operation of an entire boiler plant, without ever going near the individual furnaces. Undoubtedly we are at present moving in that direction, and the design of such a combustion-control system

would not present serious difficulties once the fuel-burning equipment had been developed to a point which would make such control practical. At present, however, the best combination seems to be a good system of equipment for automatic control of combustion, combined with expert supervision of the individual furnaces.

DISCUSSION

ARTHUR MCGONAGLE:* I should like to ask Mr. Peebles under what conditions it is possible, with proper efficiency, to control stoker speeds automatically?

T. A. PEEBLES: I would say that in most cases the speed of the stoker should be controlled, always bearing in mind that a very radical change in the conditions will require attention on the part of an operator. I think that in a plant which is getting coal from a single source and has its own crushing equipment so that that coal is properly crushed, so that exceedingly large changes in the condition of the coal do not exist, the speed of the stoker can be controlled automatically and not require much attention.

My idea is that hand adjustment of stoker speed is required in plants such as some that I know of where they will buy any coal that is rejected by anyone else. With such coal I do not think it would be practicable to put in an automatic control system and then expect it to run month in and month out without any hand adjustment of the stoker speed.

ARTHUR MCGONAGLE: Then it would be practicable to control the stoker speed automatically as long as the same quality of fuel was being used?

T. A. PEEBLES: Yes.

ARTHUR MCGONAGLE: What I had particularly in mind was that where there were great variations of load and variations of demand, and the steam pressure went down, and the stokers speeded up, and we came to a point where the regulator would reduce the speed, the fire would have an impulse that would carry the pressure

*Consulting Engineer, Pittsburgh.

up still further after the stoker speed had been reduced, and the same thing would work in the opposite direction. Some people object to the automatic control of stoker speed on the ground that you are likely to have holes in the fire.

T. A. PEEBLES: Holes in the fire result primarily from improper control of stoker speed. This can be most clearly illustrated in the case of the traveling grate. Assume, for instance, that fuel is being burned at a rate equivalent to a grate travel of six inches per minute, the fuel bed is burning away at the rear at the same rate, and, if the stoker should be stopped, the fire would rapidly burn at the rear. If air be supplied in sufficient amount to burn off the fuel bed at the rate of six inches per minute and the stoker speed be maintained uniformly at six inches per minute, the fire should continue to burn off at the same place. If an average stoker speed of six inches per minute should be obtained by alternate periods of operation at three inches per minute and nine inches per minute, the correct amount of fuel to be supplied by the fuel bed would never be in the right condition. It is for this reason that automatic control of the stoker speed is desirable. The feeding of fuel at a rate corresponding to the rate of combustion tends to keep the fire in a uniform condition which is, of course, necessary for the best results.

E. M. BOUTON:* I should like to ask if the volume of air in cubic feet per minute is assumed to be directly proportional to the flow of steam. If this is the case, would it be correct to assume that the drop in pressure through the furnace should be kept proportional to the boiler rating?

T. A. PEEBLES: For the best results there should be a relation between the air supply to the furnace and the steam delivered from the boiler. There are various ways of accomplishing this result, but some one of them should always be employed. It is not necessary that the momentary rate of air supply be equal to the momentary rate of steam delivered from the boiler, because there are other factors in addition to the rate of combustion that affect the steam delivery of a boiler. When the steam pressure is rising, less steam will be delivered

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by a boiler than when the steam pressure is falling, even when the rate of heat absorption by the boiler remains constant. The rate of steam delivery is also affected by the water-supply to the boiler, and it is neither necessary nor desirable that the air supply be adjusted for variations in steam delivery produced by conditions of this kind.

JOSEPH BRESLOVE:* I rather wish to indorse the author's thought on the necessity for regulation, particularly on small and medium-sized plants. A great deal of attention has been placed on the large stations which may be called super-stations or not, as you wish, where they have high-class operators that know what combustion is and how it is controlled. In the small station, of which there are a great number and probably always will be, the men in charge of the boiler room are, however, generally of a lower order. In the first place, the plant is small and can not afford to pay the high-class man. Aside from the matter of salary, the high-class man wouldn't stay there, because the plant isn't big enough for him. With the type of man generally employed, if the fire gets too high he will let it burn down, and, if too low, he will put more coal in. His draft regulation consists in opening or closing the furnace doors. The necessity for some form of automatic regulation in the smaller boiler room is, therefore, very important.

It is an impossibility (and Mr. Peebles is the first man that I have come across recently to bring that out forcibly) to keep the operators from putting too many boilers on the line. A time comes in the life of a small plant when the boilers are clogged up with scale, the coal may not be so good, they may not know what a soot blower is, and the output of steam falls off. Then a new boiler is bought, and because they have that new boiler they will run it. It may be that all of the boilers are not up to rating, or possibly a little over, but they will put on another one. It is only with automatic regulation that you can determine how much of a load you are going to carry on a particular boiler, and that will definitely determine how many boilers will go on the line.

The sad part of this is that in the small station where the load is small you can not afford an expensive or complicated form of automatic control, and that is where it is needed most.

*Consulting Engineer, Pittsburgh.

What are we going to do to get something that is very simple and inexpensive, whether for stoker feed or powdered coal? It need not be of the highest efficiency, but must have simplicity and still give fair regulation. That is the real problem for the smaller stations.

G. G. BELL:* Automatic control of combustion has been installed in a great number of the big power-plants built in the last few years. Probably the greatest demand for it is in those plants subject to rapid fluctuations in load; it is difficult to maintain high efficiency where there is a great variation in the demand for steam. We install automatic control in order to relieve the firemen of a portion of their duties, and let them pay more attention to those fuel-bed conditions which will increase efficiency.

The amount of attention required by equipment for automatic control is probably a function of the type of coal burned, and the capacity at which the boiler is being operated, as well as the design of the equipment itself. We have a number of motor-driven fans which are operated by push-button control, and have had to place position indicators on the control board so that the fireman could see how many notches he had moved the controller. Experience with expensive types of motors and complicated controls has led us to believe that with our relatively low-priced coal we are not justified in spending money for these expensive drives. The only saving is a reduction in the energy losses off peak. Damper control is much better from the standpoint of automatic operation; and the value of the off-peak current saved, when no credit can be given for capacity, is very low. This probably is not the case where coal is high priced and a premium is placed upon efficiency.

All sorts of mechanical equipment require attention, and automatic control is no exception; and in each plant in which it is installed it must be some person's business to understand it thoroughly and to inspect it regularly and give it such attention as it may need to keep it in first-class working condition.

With the large investment in the big boilers and the great amount of coal burned per boiler per year, it takes but a small increase in capacity or saving in fuel to justify the investment in automatic

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regulation. Operators' wages in six months will equal the price of automatic regulation, so a very slight decrease in the number of operators required will justify the investment in automatic control for large boilers, at least.

Mr. Peebles and Mr. Breslove have both mentioned the poor results obtained when underloading boilers. The superintendent of the Weymouth station told a number of us the other day that if they operated three boilers in place of two which it takes to produce steam for one of their main turbines, it requires about 500 B.t.u. per kilowatt additional, or an increase in the coal consumption of 3½ per cent. The Weymouth station is very well designed, the operators are skilled, and the fuel burned is of a high quality; so this gives an indication of the effect of underloading boilers, even under the most favorable circumstances.

W. E. Fohl, *Chairman*:* I don't know very much about automatic control, but it seems to me it should be an advantage in any steam plant. I am speaking now from the experience that we have gained in our own company and the National Tube Company. Six years ago we put in our first installation in one of the works along the river. After it had been in operation about a year we checked the cost of producing the steam and found that we had made a saving of 17 per cent., which represented a saving of about $17,700. We thought that was pretty good. We checked up another plant and found that we had saved about 7¾ per cent., which represented a saving of $10,500. I think we saved at least five per cent. in each of our installations, and I judge that in every case the installation paid for itself in less than a year—sometimes in four to six months. That sounds like a pretty good investment.

G. B. Page:† I should like to confirm and indorse some of the author's remarks. A certain good friend of mine terms equipment for control of combustion a tool in a man's hand to help him to do certain work. It is true that this equipment does not in every instance replace a man, but it enables the man in the plant to do more accurate work. It is true that the equipment does not overcome the mechanical char-

*Consulting Mining Engineer, Pittsburgh.
†Mechanical Engineer, Pittsburgh.

acteristics of the fuel bed, but those things are made much easier by the installation of such equipment.

The matter of regulating fuel feed, it seems to me, regardless of the type—that is whether it is powdered fuel or stoker equipment—is more particularly the matter of the personal human equation. Despite a certain amount of variation in B.t.u. delivered to the furnace, due to the varying characteristics and sizes of coal, it is next to impossible to look into the furnace and tell accurately how much coal is being burned out of the bed at any given time and for how long a period; hence, if your fuel feed is automatically controlled, you can more nearly approach the condition where, having burned out one pound of coal, you deliver one pound of new coal in its place.

Some years ago I was associated with a certain stoker company and felt at that time that the matter of stoker speed should be left to hand regulation. To-day I am satisfied that, for the single matter of the personal human equation, automatic control of the fuel feed is well worth while, for it will keep a more uniform and a more stable fuel bed.

To-day the matter of regulation is being more seriously considered than ever before. As Mr. Peebles has said, the matter of coal prices of a few years ago worked against the installation of control equipment in this vicinity, but to-day it seems to me that it is necessary to put in control equipment if you are going to realize on the premium you pay for efficiency in your combustion equipment and your boiler. In other words, why pay a premium on boiler and furnace efficiency and then buy your control equipment on price?

ARTHUR McGONAGLE: We do use automatic control on stoker speed, but where your coal condition is bad, and, where the fluctuations in load are such that the automatic control will not handle it fast enough, we just turn off the automatic control, and when conditions come back to where it is more regular we turn it on again. The actual inertia of the fuel bed itself acts as a storage battery on the system, and the change in fuel bed does not necessarily occur as rapidly or with as wide a fluctuation as the load does, and in that case, if you have a preference for automatic control, you can allow your stoker to be automatically controlled. If you don't think it is doing any good and you can do better by shutting it off, you can do that; both systems are used.

BOARD OF DIRECTION

September

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the William Penn Hotel, Tuesday, September 21, at 4:15 P. M., President W. E. Fohl presiding, Messrs. Ladd, Hunter, Goodspeed, Weldin, Affelder, Spellmire, Fieldner, Humphrey, Eavenson, Edgar and the Secretary being present.

The President called the meeting to order and stated that before taking up the regular order of business he would call on Mr. Knowles and Dr. Bishop, who were present at his invitation to speak to the Board on the subjuct of the formation of an Engineering Council in the Chamber of Commerce. Mr. Fohl called attention to the fact that this matter had been presented to the Board on May 18, at which time it was decided that while our Society wished to co-operate in every way with the Chamber of Commerce, it was felt our Civic Affairs Committee was taking care of the work for which this Council would be organized and the Secretary was, therefore, instructed to write the Chamber of Commerce to this effect, telling them that we hoped they would call upon us whenever we could be of assistance to them.

Mr. Knowles then addressed the Board, giving them in brief an outline of the object of this Council and stating that he felt the Society would be overlooking an opportunity if they did not offer their services in assisting in this movement for the organization of the Council. He stated further that he felt if the Board took favorable action, the committee should be appointed composed of non-members of the Board, who would be instructed to go into the matter thoroughly and take the necessary steps of organization.

The President called Dr. Bishop, who emphasized the need of such a Council for entertaining out-of-town engineers. Dr. Bishop said he had been called upon, as a member of the Chamber of Commerce, to entertain out-of-town engineers, mostly from foreign shores, and that there had been no engineering committee in the Chamber to assist him. He also called attention to the fact that these foreigners were always particularly interested in meeting the engineers in the various cities they visited.

The President then thanked Mr. Knowles and Dr. Bishop for their interest and their appearance here to-day, and they then retired from the meeting.

A general discussion on the subject followed and it was regularly moved and carried that the matter be tabled.

The minutes of the last regular meeting, held June 15, were approved without reading.

Applications from the following applicants having been published to the Society, pursuant to the action of the Board, were elected to membership:

MEMBERS

Dyche, H. E.	Hughes, I. Lamont
Bennett, George Lewis	Waldorf, Fred

ASSOCIATE MEMBERS

Stuart, Gordon W.	Worthington, E. L.

JUNIORS

Hilton, Winfield Reed	Hoffman, James Thomas

Smyers, William H.

Applications for membership were received from the following gentlemen and their names ordered published to the Society. Assignment to the various grades of membership is as follows:

MEMBERS

Bauer, Ralph G.	Hoffacker, B. F.
Bradley, John Rodgers	Koch, Richard
Flanagan, Walter N.	Meinecke, Heins
Paulsen, William R.	Soderstrom, Karl Adolf

ASSOCIATE MEMBERS

Collins, Tappan	Kroske, Jacob Frederick
Dinneen, William Thomas	Nation, Robert B.
Durkee, E. J.	Overton, R. M.
Kohn, Roy E.	Rowland, Roger W.

ASSOCIATES

Klos, Clifford H.	Chase, Walter F.

JUNIOR

Brown, Albert Abraham

STUDENT JUNIOR

Motok, George I.

Applications for reinstatement were received from the following gentlemen and, after discussion, the Secretary was requested to advise them of their reinstatement to membership:

Hutchinson, George H. (Member) Reno, Edwin S. (Associate Member)

Letters of resignation were received from the following members and, after discussion, they were ordered accepted:

Mann, Nelson T. Evans, Roger M.

The reports of the Secretary showing the condition of the Society at the close of business June 30, July 31 and August 31, having been audited by the Finance Committee, were approved.

The Secretary reported on behalf of Mr. Clifford, Chairman of the Entertainment Committee, stating that the committee had held a meeting to make arrangements for the fall activities and had decided to hold a Ladies' Night party on Saturday evening, October 30. Preliminary arrangements were also made for the Annual Dinner to be held the latter part of January.

Mr. Weldin, Chairman of the House Committee, reported an evening attendance of 1040 for the months of June, July and August. He further called the attention of the Board to the fact that our lease for the hotel expires November 1 and there is a possibility that we may have to pay an increase in rent. Mr. Weldin also reported that the House Committee had a meeting with a special committee appointed on ventilation and that, after a test had been run in our rooms, the report had been drawn up and presented to the hotel. The management will carry out the suggestions made in that report and the committee will make final report to the Board after they have made further tests of the ventilation when the new equipment has been installed.

Mr. Goodspeed, Chairman of the Publication Committee, reported that the program as arranged last spring gave promise of being carried out and quite a number of prominent speakers were on the list for fall meetings.

The question of inviting visiting members of the A. I. M. & M. E. attending their coming meeting in Pittsburgh on October 6, 7, 8 and 9 to make use of the Society quarters was brought up for discussion, and it was

regularly moved and carried that the Secretary write a letter to the Secretary of the Mining Institute, sending copy to Mr. Bright, extending this invitation, and it was further recommended that special guest cards be printed and given to the Registration Committee in order that they may be distributed among their visiting members.

Mr. Affelder stated that he had a matter which he wished to bring to the attention of the Board, regarding a gathering of alumni of Penn State and Notre Dame on October 16 and Penn State and University of Pennsylvania on November 6, to receive results of the two games by providing them by wire of the Western Union. Mr. Affelder stated that in past years these gatherings had been held in the auditorium of the Chamber of Commerce, but this year they had been unable to secure reservations and the rooms of the Engineers' Society had been suggested as an alternate. He stated further that bringing these men into our quarters would create an interest in the engineers and the meetings would not in any way interfere with the regular Saturday afternoon attendance for bridge, chess, etc.

After a general discussion, it was regularly moved and carried that the House Committee be authorized to use our Club Room on the two Saturday afternoons at a price of $20.00 per game.

Mr. Affelder also called the attention of the Board to the booklets being given out by the local chapter of the A. I. M. & M. E. for their coming convention, stating that these were the most complete booklets on the city of Pittsburgh published for some time and suggested that the Engineers' Society purchase some of these booklets to have on hand.

After a general discussion, it was moved and carried that the Finance Committee be authorized to purchase a number of these booklets if they decide they would be of value to the Society.

The Secretary presented a suggestion for the promotion of a Pittsburgh Engineering Standard Committee to co-operate with the American Engineering Standards Committee of New York. This subject was brought up for discussion at the recent conference of local society secretaries attended by the Secretary, and attention was called to the work done by the Cleveland Engineering Society who has formed such a committee. Attention was called to the fact that Mr. C. E. Skinner, National Chairman, National Engineering Standards Committee, was the local chairman and would probably be willing to attend the next meeting of the Board and advise how the Society could co-operate with the national organization. After discussion it was moved and carried that the Secretary be instructed to notify Mr. Skinner to attend the meeting of the Board on October 19 to advise how we could be of assistance to him.

The meeting adjourned at 5:30 P. M.

K. F. Treschow, *Secretary.*

BOARD OF DIRECTION

October

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the William Penn Hotel, Tuesday, October 19, at 4:10 P. M., President W. E. Fohl presiding, Messrs. Hunter, Goodspeed, Clifford, Affelder, Spellmire, Fieldner, Hopkins, Shaw, Covell, Humphrey and the Secretary being present.

The minutes of the last regular meeting, held September 21, were approved without reading.

Applications from the following applicants having been published to the Society, pursuant to the action of the Board, were elected to membership:

MEMBERS

Bauer, Ralph G.
Meinecke, Heins
Bradley, John Rodgers
Paulsen, William R.
Flanagan, Walter N.
Hoffacker, B. F.
Koch, Richard
Soderstrom, Karl Adolf

ASSOCIATE MEMBERS

Collins, Tappan
Dinneen, William Thomas
Durkee, E. L.
Kohn, Roy E.
Kroske, J. Frederick
Nation, Robert B.
Overton, R. M.
Rowland, Roger W.

ASSOCIATES

Chase, Walter F.
Klos, Clifford H.

JUNIOR

Brown, Albert A.

STUDENT JUNIOR

Motok, George I.

Applications for membership were received from the following gentlemen and their names ordered published to the Society. Assignment to the various grades of membership is as follows:

MEMBERS

Hirsch, William L.
Merrill, Ferrand S.
Mikaloff, John P., Jr.

ASSOCIATE MEMBERS

Leisenring, William Jessup
Mauser, Louis K.

ASSOCIATES

Kern, Frederick E.
Bain, George F.
Thomas, Walter Scott

Application for reinstatement was received from Mr. M. D. Cooper and, after discussion, the Secretary was requested to write him advising him of his reinstatement to membership.

Letters of resignation were received from the following members and, after discussion, they were ordered accepted:

Brandt, C. A.
Herring, T. F.
Klingelhofer, E. K.

The Secretary reported the death of the following members:

Goldie, William.......Joined Nov., 1894 Died July 2, 1926
Wood, Douglass........Joined June, 1926 Died Sept. 30, 1926

The report of the Secretary showing the condition of the Society at the close of business September 30, 1926, having been audited by the Finance Committee, was approved.

Mr. Clifford, Chairman of the Entertainment Committee, reported that arrangements had been made for a Ladies' Night party to be held Monday evening, November 8. The committee has also held preliminary meeting on

plans for our Annual Dinner and hopes to have some definite word as to speakers in the near future. The Banquet will be held, as usual, the latter part of January.

The Secretary reported, in the absence of Mr. Weldin, Chairman of the House Committee, an evening attendance of 381 for the month of September. They also reported that the management of the William Penn Hotel had approached them regarding an increase in rent and, after a preliminary conference, a tentative figure of $50.00 was set for the increase. The committee feels that it is a fair amount and recommends that the Board authorize this increase. It was moved and carried that the House Committee be authorized to sign a lease for the coming year, at an increase of $50.00 per month.

Mr. Affelder, Chairman of the Membership Committee, stated that one meeting of the committee has been held to go over applications received since the last meeting of the Board and make assignment to various grades of membership and transact any other business coming before the committee.

Mr. Goodspeed, Chairman of the Publication Committee, reported that the program as laid out this spring gave promise of being carried out as arranged.

The Secretary read a letter from Mr. George S. Davison, regarding a letter received from Mr. Thomas Rodd, a member of the Society, in which he offered to present to the Society a complete set of photographs of Pennsylvania Railroad presidents. After discussion, the Secretary was instructed to write Mr. Rodd, advising that we appreciated his offer and would be glad to accept had we space on our walls to place them, but under the circumstances were obliged to decline.

The President stated that, in accordance with action of the Board at the last meeting, Mr. Skinner had been invited to attend this meeting and speak on the subject of organization of Pittsburgh Engineering Standards Committee, the same as that adopted in Cleveland. Unfortunately, Mr. Skinner was unable to attend on account of being out of the city and this matter was referred over to the next Board meeting.

The matter of the promotion of an Engineering Council in the Chamber of Commerce presented to the Board at its last meeting by Mr. Knowles was again brought up for discussion, attention being called to the fact that a number of the present directors of the Chamber of Commerce were members of this Society and were interested in this subject. After discussion it was moved and carried that this matter be referred to Mr. Spellmire with the request that he approach Mr. Knowles and secure further information and report back to the Board at its next meeting.

The meeting adjourned at 5:15 P. M.

K. F. Treschow, *Secretary.*

BOARD OF DIRECTION

November

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the William Penn Hotel, Tuesday, November 16, at 4:10 P. M., President W. E. Fohl presiding, Messrs. Hunter, Weldin, Hopkins, Shaw, Covell, Rice, Humphrey and the Secretary being present.

The minutes of the last regular meeting, held October 19, were approved without reading.

Applications from the following applicants having been published to the Society, pursuant to the action of the Board, were elected to membership:

MEMBERS

Hirsh, William L.
Mikaloff, John P., Jr.
Merrill, Ferrand S.

ASSOCIATE MEMBERS

Leisenring, William Jessup
Mauser, Louis K.

ASSOCIATES

Bain, George F.
Thomas, Walter Scott
Kern, Frederick E.

Applications for membership were received from the following gentlemen and their names ordered published to the Society. Assignment to the various grades of membership is as follows:

MEMBERS

Arvidson, C. G.
Hellmund, R. E.
Kirk, R. L.
Lewin, Francis A. W.
Mundo, C. J.
Phillips, L.
Powel, C. A.
Rittman, W. F.
Roughen, R. H.
Sborigi, Guido V.
Schuehert, Joseph S.
Ward, Vernon Champlin
Whitwell, George E.

ASSOCIATE MEMBERS

Kendall, Theodore H.
McCullough, John Lewis
Metzger, William Fred
Tredway, Alexander C.
Wilson, Howard Mitchell
Lovett, S. C.

ASSOCIATES

Anderson, Walker
Bingay, Robert V.
Cooke, Milburn W.
Downer, Charles B.
Ghen, Melville W.
Hill, Charles M.
Knaell, Kenneth K.
McElheny, George B.
McGrath, Martin H.
McKee, Frederick Chadwick
Ousler, G. W.
Perkins, E. E., Jr.
Ronay, Julius S.
Roth, James D.
Rudd, Harold H.
Sill, Edgar T.
Sinclair, C. T.
Sutherland, George
Walworth, Stanley L.

JUNIORS

Greg, Victor C.
Peterson, V. H.
LaBaron, George I.

STUDENT JUNIOR

Smith, I. L.

Letter of resignation was received from Mr. Charles M. Brown and, after discussion, the Secretary was requested to write him accepting his resignation.

Application for transfer to higher grade of membership was received from Mr. E. S. Reno and, after discussion, the Secretary was requested to advise him of his transfer to the grade of Member.

The Secretary reported the death of the following members:

Harry W. B. Gibson	Joined Jan., 1899	Died Nov. 2, 1926
John Frew Scott	Joined Mar., 1922	Died Nov. 1, 1926

The report of the Secretary showing the condition of the Society at the close of business October 31, having been audited by the Finance Committee, was approved.

The Secretary reported in the absence of Mr. T. C. Clifford, Chairman of the Entertainment Committee, that we had a very successful Ladies' Night party on November 8 with the largest attendance we ever had. Arrangements are also under way for our Dinner to be held the latter part of January and the committee hopes to have a report on the speakers for the next meeting of the Board.

In the absence of Mr. Affelder, Chairman of the Membership Committee, the Secretary reported that one meeting of the committee had been held to go over applications received since the last meeting and assign them to the grades of membership.

Mr. W. A. Weldin, Chairman of the House Committee, reported an evening attendance of 360 for the month of October.

In accordance with the By-Laws of the Society, the Secretary presented a report of the Nominating Committee appointed to nominate officers for the Society, as follows:

To the Board of Direction,
Engineers' Society of Western Pennsylvania.

DEAR SIRS:

The Nominating Committee appointed to nominate officers for the ensuing year held a meeting in the Society Rooms, November 10, and submit the following members as nominees for the offices indicated:

President	George T. Ladd
Vice President	J. N. Chester
Treasurer	A. Stucki
Directors	A. C. Fieldner V. R. Covell

Respectfully submitted,

JAMES O. HANDY, *Chairman,*
H. N. EAVENSON,
R. W. ANDREWS,
J. F. LABOON,
J. I. THOMPSON,
Nominating Committee.

It was regularly moved and carried that the report be approved and the Secretary instructed to publish these names on our next announcement in accordance with the By-Laws.

The Secretary brought up the matter of a committee of our Society to co-operate with the American Engineering Standards Committee, which was brought up at the last meeting of the Board, at which the Secretary was instructed to notify Mr. Skinner to attend the meeting and give the Board the benefit of his advice regarding the formation of such a committee. The Secretary reported that unfortunately Mr. Skinner had been called to New York on the date of both Board meetings and that he suggested that the Board go ahead and appoint a committee of three or four which could meet with him at some time in the near future. This committee could then report back to the Board with a definite plan of organization or other recommendation.

After discussion, it was regularly moved and carried that the President be authorized to appoint such a committee, said committee to report back to the Board at the December meeting.

On motion, duly seconded and carried, the meeting adjourned at 5:30 P. M.

K. F. TRESCHOW, *Secretary.*

ELECTRICAL SECTION

September

The regular monthly meeting of the Electrical Section of the Engineers' Society of Western Pennsylvania was held jointly with the Pittsburgh Section of the American Institute of Electrical Engineers in the Chamber of Commerce Building, Tuesday, September 14, at 8:00 P. M., 220 members and visitors being present.

The meeting was called to order by Secretary and Acting Chairman Simons, of the American Institute of Electrical Engineers. Owing to a meeting of the Executive Committee of the Second district being held in Pittsburgh, several naional society officers and a number of officers of local sections from Cleveland, Buffalo, Erie, Cincinnati, Baltimore and Philadelphia attended the meeting and were introduced by the Chairman.

The meeting was then turned over to Chairman Humphrey, of the Electrical Section of the Society.

The minutes of the last meeting, being the organization meeting, were read and approved.

The Chairman announced the appointment, in compliance with action taken at the last meeting, of the following committees:

Committee on Constitution and By-Laws—M. E. Skinner, Chairman; H. E. Dyche and J. M. Miller.

Committee on Program — A. Pinkerton, Chairman; J. A. Milady and R. L. Ralph.

No further business coming before the Section, the paper of the evening was presented by Paul B. Findley, Electrical Engineer, Bell Telephone Laboratories (formerly of Pittsburgh), on the subject of "New Landmarks in Electrical Communication."

Short discussion followed the presentation of the meeting.

Meeting adjourned at 10:20 P. M.

K. F. TRESCHOW, *Secretary.*

MINING SECTION

The regular bi-monthly meeting of the Mining Section of the Engineers' Society of Western Pennsylvania was held in the Blue Room, William Penn Hotel, Tuesday, September 28, at 8:20 P. M., Chairman N. F. Hopkins presiding, 15 members and visitors being present.

The minutes of the last meeting, held March 30, were read and approved.

There being no further business before the Section, the paper of the evening, on "Mine Timber Standardization from Standpoint of the Manufacturer," was presented by Mr. Ralph A. Smith, Secretary, Pennsylvania Forest Products Manufacturers' Association, Tyrone, Pa.

The ensuing discussion was participated in by: S. E. Workman, P. A. for Lumber, Pittsburgh Coal Co.; N. F. Hopkins, Civil & Mining Engr, Harrop & Hopkins; L. D. Tracy, Coal Mining Engr, U. S. Bureau of Mines; and the author.

On motion, duly seconded and carried, a vote of thanks was extended to the author for his very interesting paper.

There being no further business, the meeting adjourned at 9:55 P. M.

K. F. Treschow, *Secretary.*

REGULAR MONTHLY MEETING

September

The four hundred and fortieth regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Blue Room, William Penn Hotel, Tuesday, September 21, at 8:12 P. M., President W. E. Fohl presiding, 68 members and visitors being present.

The minutes of the last meeting, held May 20, were read and approved.

The Board of Direction reported the election of four applicants to the grade of Member, two to the grade of Associate Member, and three to the grade of Junior. There were two reinstatements, two resignations accepted, and fifteen delinquents dropped.

No further business coming before the Society, the paper of the evening was presented by Dr. C. G. Abbot, Assistant Secretary, Smithsonian Institution, Washington, D. C., on "Long Range Weather Forecasting."

The ensuing discussion was participated in by: A. C. Fieldner, Supt, Pittsburgh Experiment Station, U. S. Bureau of Mines; G. S. Humphrey, Elec. Engr, West Penn Power System; W. E. Fohl, Consulting Mining Engineer; G. P. Thomas, Pres, Thomas Spacing Machine Co.; Emil Hallgren, Designing Engr, Blaw-Knox Co.; Edward Godfrey, Struct. Engr, Robert W. Hunt Co.; and the author.

A rising vote of thanks was extended to Dr. Abbot for his very interesting talk.

The meeting adjourned at 9:50 P. M.

K. F. Treschow, *Secretary.*

MECHANICAL SECTION

The regular bi-monthly meeting of the Mechanical Section of the Engineers' Society of Western Pennsylvania was held jointly with the Pittsburgh Section of the American Society of Mechanical Engineers, Tuesday evening, October 5, in the Blue Room of the William Penn Hotel, Chairman William Shaw presiding, 78 members and visitors being present.

The minutes of the last meeting, held June 1, were read and approved.

There being no further business coming before the Section, the paper of the evening, on "The Design of High-Pressure Industrial Power Plants," was presented by Mr. R. S. Bayntun, The Chesapeake Corporation, West Point, Va.

The ensuing discussion was participated in by: W. D. Canan, Mech. Engr, Rust Engineering Company; B. M. Herr, Partner, Herr, Harris & Co.; F. R. Magill, Sales Engr, Dingle-Clark Co.; C. G. Thornburgh, Engr, Rust Engineering Co.; W. W. Pratt, Westinghouse Elec. & Mfg. Co.; William Shaw, Power Engr, Mechanical Div, Bureau of Water, City of Pittsburgh; Clarence D. Foight, Engr, Rust Engineering Co.; G. E. Stoltz, Mgr, Industrial Engineering, Westinghouse Elec. & Mfg. Co.; John A. Graham, Supt. Buildings & Grounds, Shady Side Academy; and the author.

On motion, a vote of thanks was extended to Mr. Bayntun for his very interesting paper.

The meeting adjourned at 10:02 P. M.

K. F. Treschow, *Secretary.*

ELECTRICAL SECTION

October

The regular monthly meeting of the Electrical Section of the Engineers' Society of Western Pennsylvania was held jointly with the Pittsburgh Section of the American Institute of Electrical Engineers in the Chamber of Commerce Building, Tuesday, October 12, at 8:00 P. M., Chairman George S. Humphrey presiding, 510 members and visitors being present.

The minutes of the last meeting, held September 14, were read and approved.

No other business coming before the Section, the paper of the evening, on "Automatic Train Control," was presented by Mr. L. F. Howard, Chief Engineer, Union Switch & Signal Co., Swissvale, Pa.

A general discussion followed the presentation of the paper.

On motion, duly seconded and carried, the meeting adjourned at 10:30 P. M.

K. F. Treschow, *Secretary.*

REGULAR MONTHLY MEETING

October

The four hundred and forty-first monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, William Penn Hotel, Tuesday, October 19, at 8:28 P. M., President W. E. Fohl presiding, 102 members and visitors being present.

The minutes of the last meeting, held September 21, were read and approved.

The Board of Direction reported the election of eight applicants to the grade of Member, eight to the grade of Associate Member, two to the grade of Associate, one to the grade of Junior and one to the grade of Student Junior, and the receipt of eight applications for membership. There was one reinstatement and three resignations accepted and two deaths reported.

No further business coming before the Society, Mr. Richard E. Enright, former Police Commissioner of New York City, made an address on "The Police and the People versus the Powers That Prey."

A general discussion followed.

On motion, duly seconded and carried, a vote of thanks was extended to Mr. Enright for his very interesting and instructive address.

On motion, the meeting adjourned at 10:35 P. M.

K. F. Treschow, *Secretary.*

ALL-DAY CONFERENCE—STEEL WORKS SECTION

An all-day conference of the Steel Works Section of the Engineers' Society of Western Pennsylvania was held in the Blue Room, William Penn Hotel, Thursday, October 28, from 9:30 A. M. to 4:00 P. M., Chairman A. C. Fieldner presiding, 150 members and visitors being present. Meeting called to order at 9:50 A. M.

The first paper presented was "Recuperators for Industrial Furnaces," by Willibald Trinks, Consulting Engineer and Professor Mechanical Engineering, Carnegie Institute of Technology, Pittsburgh, Pa.

The second paper presented was "Recuperators Applied to Open Hearth Furnaces," by W. H. Fitch, Consulting Engineer, Allentown, Pa.

The third paper presented was "Air Preheaters for Boilers," by R. E. Butler, Engineer, Babcock & Wilcox Co., Pittsburgh, Pa.

The ensuing discussion was participated in by: F. W. Manker, V. P., Surface Combustion Co., New York, N. Y.; W. C. Buell, Jr., Mech. Engr, Rust Engineering Co.; D. B. Hendryx, V. P., Hanley Company, Bradford, Pa.; V. P. Griffin, Comb. Engr, Duquesne Light Co.; Victor Windett, Engr, Gas Producer Div, Wellman-Seaver-Morgan Co., Cleveland, O.; W. Dyrssen, Chief Engr, Blaw-Knox Co., Blawnox, Pa.; John S. Unger, Mgr, Research Bureau, Carnegie Steel Co.; T. J. McLoughlin, Fuel Engr, Carnegie Steel Co., Duquesne, Pa.; Howard Butt, The Air Preheater Corp, New York, N. Y.; A. C. Fieldner, Supt, Pittsburgh Experiment Station, U. S. Bureau of Mines; A. L. Culbertson, Asst. Mgr., Chapman Engineering Co., Mt. Vernon, O.; R. E. Cramer, Asst. Dist. Engr, American Steel & Wire Co.; B. C. Sprague, Elec. Engr, West Penn Power Co.; K. C. McCutcheon, American Rolling Mill Co., Ashland, Ky.; C. D. Smith, Cns. Engr, Washington, Pa.; and the authors.

On motion, duly seconded and carried, a vote of thanks was extended to the speakers for their very instructive papers.

The meeting adjourned at 4:15 P. M.

K. F. TRESCHOW, *Secretary.*

ALL-DAY CONFERENCE—CIVIL SECTION

An all-day conference of the Civil Section of the Engineers' Society of Western Pennsylvania was held in the Blue Room, William Penn Hotel, Thursday, November 4, from 9:30 A. M. to 4:00 P. M. The meeting was called to order by Mr. V. R. Covell, Chairman, at 9:45 A. M., 110 members and visitors being present.

The first paper was presented on "Evolution of Steel-Skeleton Type of Building" by Robins Fleming, Structural Engineer, American Bridge Company, New York, N. Y.

The second paper presented was "Recent Development of Rolled Structural Sections," by A. E. Crockett, Manager, Bureau of Instruction, Jones & Laughlin Steel Corporation, Pittsburgh, Pa.

The third paper presented was "Foundations," by George R. Johnson, Vice President, The Foundation Company, Pittsburgh, Pa.

The fourth paper presented was "Effect of Gunite Encasement on Structural Steel," by B. C. Collier, President, Cement Gun Company, Inc., Allentown, Pa.

The ensuing discussion was participated in by: J. A. McEwen, Sales Mgr, Pittsburgh Bridge & Iron Co.; Albert M. Candy, Gen. Engr, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.; C. S. Boardman, Sales Engr, Jones & Laughlin Steel Corp.; Harold S. Thomas, Associate Professor, Civil Engineering, Carnegie Institute of Technology; H. O. Hill, Power Engr, Riter-Conley Co.; C. N. Haggart, Structural Engr, Private Practice, Pittsburgh; W. W. Hendrix, Sales Engr, Pittsburgh-Des Moines Steel Co.; V. C. Ward, Engr, Junior Beam Dept, Jones & Laughlin Steel Corp.; F. M. McCullough, Professor, Civil Engineering, Carnegie Institute of Technology; R. P. Forsberg, Prin. Asst. Engr, Pittsburgh & Lake Erie R. R.; P. W. Price, Prin. Asst. Engr, Bureau of Bridges, Dept. Public Works, Allegheny County; R. B. Horner, Struct. Engr, Duquesne Light Co.; Reuben Davis, V. P., Foundation Co., New York, N. Y.; F. J. Evans, Instructor, Civil Engineering, Carnegie Institute of Technology; Arthur W. Engel, Engr, American Bridge Co.; V. R. Covell, Chief Engr, Bureau of Bridges, Dept. Public Works, Allegheny County; C. W. Littler, Chief Engr, Jones & Laughlin Steel Corp.,

Aliquippa, Pa.; J. R. Shank, Ohio State University, Columbus, O.; George C. Ramsdell, Engr, Travelers Insurance Co.; W. I. Parry, Engr, Salesman, Carnegie Steel Co.; and the authors.

A vote of thanks was extended to the authors of these papers for their valuable contributions.

The meeting adjourned at 4:35 P. M.

K. F. Treschow, *Secretary.*

JOINT MEETING—ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA AND ILLUMINATING ENGINEERING SOCIETY, PITTSBURGH CHAPTER—ORGANIZATION MEETING—ILLUMINATING ENGINEERS' SECTION

The organization meeting of the Illuminating Engineers' Section of the Engineers' Society of Western Pennsylvania was held in the Blue Room, William Penn Hotel, Monday evening, November 15, at 8:15 o'clock, Vice President John A. Hunter presiding, 50 members and visitors being present.

Mr. Hunter stated that the meeting had been called to organize an Illuminating Engineers' Section of the Engineers' Society to hold joint meetings with the Pittsburgh Chapter of the Illuminating Engineering Society, and to elect officers for the Section. The report of the Nominating Committee was presented as follows:

To Officers and Members,
Illuminating Engineers' Section.

Dear Sirs:

Your Nominating Committee appointed to nominate officers for the Executive Committee of the newly formed Illuminating Engineers' Section met to-day at 12:30 and nominate the following:

Chairman...H. L. Johnston
Vice Chairman ....H. S. Hower
Directors.................................. { E. L. Worthington, Arthur McGonagle, S. C. Lovett, J. G. Allen, J. A. Hoeveler }

Respectfully submitted,

J. I. Alexander, *Chairman,*
Joseph Bryan,
William Shaw,
Nominating Committee.

On motion, duly seconded and carried, the nominations were closed and the Secretary instructed to cast a unanimous ballot of the members present in favor of the election of the persons nominated, and they were therefore declared elected. Mr. Johnston, the newly elected Chairman, then took the chair.

No further business coming before the meeting, the paper of the evening was presented by Mr. Samuel G. Hibben, Manager, Commercial Engineering Department, Westinghouse Lamp Company, Bloomfield, N. J., on "Display Lighting at the Sesqui-Centennial."

The ensuing discussion was participated in by: Mr. Goldbeck; J. A. Hoeveler, Mgr, Engineering Dept., Pittsburgh Reflector Co.; G. W. Thomas, Chf. Engr, H. H. Robertson Co.; W. H. Horton, West Penn Power Co.; P. Carraux; and the author.

On motion, duly seconded and carried, a vote of thanks was extended to Mr. Hibben for his very interesting paper.

The meeting adjourned at 10:15 P. M.

K. F. TRESCHOW, *Secretary.*

REGULAR MONTHLY MEETING

November

The four hundred and forty-second regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Blue Room, William Penn Hotel, Tuesday evening, November 16, at 8:15 P. M., President W. E. Fohl presiding, 38 members and visitors being present.

The minutes of the last regular meeting, held October 19, were read and approved.

The Board of Direction reported the election of three applicants to the grade of Member, two to the grade of Associate Member and three to the grade of Associate; and the receipt of forty-two applications for membership, twenty-seven of these being members of the A. I. E. E. who joined on invitation to become members of the Society. One resignation was accepted; one reinstatement and one member was transferred to higher grade. Two deaths were reported.

No further business coming before the Society, the paper of the evening was presented, on "Manufacture of Artificial Silk," by G. J. Esselen, Jr., Vice President, Skinner, Sherman & Esselen, Boston, Mass.

A general discussion followed the presentation of the paper.

On motion, duly seconded and carried, a vote of thanks was extended to Mr. Esselen for his very interesting paper.

The meeting adjourned at 9:25 P. M.

K. F. TRESCHOW, *Secretary.*

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PROFESSIONAL CARDS

Vol. 42 JANUARY 1927 No. 10

PROCEEDINGS

OF THE

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA

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PROCEEDINGS OF THE

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RECUPERATORS FOR INDUSTRIAL FURNACES*

By Willibald Trinks†

In the modern sense of the word a recuperator is a heat exchanger for transferring heat in a steady flow from hot products of combustion through a wall to air which is to serve for combustion in an industrial furnace. While air preheaters for boilers serve the same purpose, they are not called recuperators. The latter term is reserved for air preheaters of industrial furnaces—that is, for reheating furnaces, annealing and heat-treating furnaces and the like.

The stack losses of simple furnaces are very great, because the products of combustion leave at a temperature in excess of that of the furnace, if they are to impart heat to the latter and to the charge. Per pound of material heated, the stack loss increases very rapidly with the furnace temperature, because the stock to be heated requires more heat, and because a smaller fraction of the heat of combustion is available. In the limiting case in which furnace temperature equals flame temperature, an infinitely large quantity of fuel would be needed. This condition is well known from metallurgical calculations and needs no further comment. The endeavor to salvage this heat by transferring it either to the incoming fuel or to the incoming air, or to both, is quite old. It was a rational step to take, and history does not record the name of the inventor of the recuperator, in contradistinction to the history of the regenerator, the inventor of which was Friedrich Siemens. The fuel saving which can be obtained by air preheating is indicated in Fig. 1.

In spite of the apparent desirability of a recuperator, it did not, for many years, take a lasting hold. Recuperators came and went. Furnace designers put them in, and furnace operators took them out. We do not have to look very far in order to find the reason for the former failure of recuperators to find favor with furnace operators. Metallic recuperators, made of cast-iron or steel, cracked, or burned out. Recuperators made of refractory materials cracked. The results were disastrous in either case. Combustion air was usually brought to the recuperator by a fan. Cracks or openings caused by burning

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away of the partition allowed the fan air to escape directly into the stack. The furnace did not receive sufficient air for combustion, and the stack was choked with cold air. In such a case the furnace operator knows how to help himself. The recuperator is by-passed; the furnace goes on without it, and the recuperator becomes a thing to

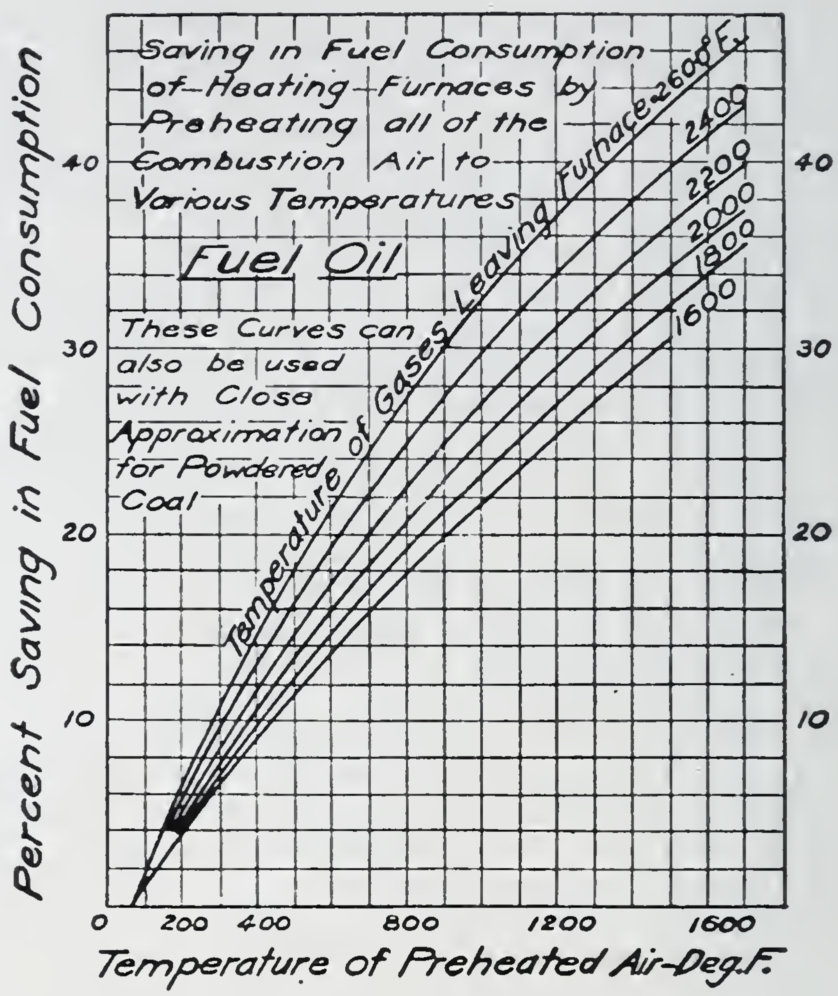

Fig. 1. Saving of Fuel by Preheating of Air.

be remembered only, passing into oblivion. Furnace operators have another grudge against recuperators. The attendants like "nice, big openings" through which they can observe the flames. If the furnace operates with "natural air," the inlet openings for that air make wonderful observation openings, whereas, with preheated recuperator air, only small, inconvenient peep-holes are provided.

In the last few years the interest in recuperators has been revived quite perceptibly. Fuel is becoming dearer, and recuperator builders have learned to avoid the old pitfalls by using better design and better materials. In spite of their progress, recuperators are by no means universally adopted. Furnaces with recuperators are still the exception rather than the rule.

This situation brings us to two cardinal questions:

1. Does it pay to use recuperators?

2. Can recuperators be built so that they are cheap, simple, and durable?

The first question is answered, at least in part, in the author's "Industrial Furnaces," volume 2,* on pages 319-326. In these pages proof is furnished that the installation of recuperators pays from 100 to 300 per cent. on the investment, if they can be made to last three years without repairs or replacement. The principle of the calculation is very simple. It compares the yearly fuel saving with the cost of investment, repair, and maintenance. The chances are that in the calculation in question the cost was taken too low, because the installation of a recuperator involves extras such as support of recuperator (or else excavation and foundation), piping, and insulation for hot-blast piping. In many furnaces we must add the cost of extra flues to collect the flue-gases and bring them to the recuperator and thence to the stack.

Furnace work is so varied that each new installation (unless exactly a duplicate of one previously made) calls for separate investigation which involves the following items:

1. Cost of fuel.

2. Load factor (fraction of total time during which furnace is in use).

3. Effect of the use of preheated air on the heating process and upon heat application.

4. Saving obtained by preheat as a function of temperature.

5. Cost of recuperator installation complete as a function of temperature preheat.

6. Cost of repairs and maintenance.

7. Cost of extra power required.

Now it stands to reason that the average industrial furnace which costs between $500 and $2000 would scarcely warrant an expensive engineering investigation, but it is also clear that recuperator builders could chart these data in the form of alinement charts or slide-rules and could equip their sales engineers to give prospective purchasers valuable engineering service at a minimum of cost.

*John Wiley & Sons, New York. 1925.

The influence of some of the items is evident. Where fuel costs next to nothing, it does not pay to install a recuperator, no matter how desirable its installation would be from the standpoint of conservation of national resources. Where a furnace is used only once in a great while, any refinement for the purpose of saving fuel is out of place.

Item 3 is less evident, but is none the less important. From the gas formula, $pv = RT = \frac{c^2}{3g}$, in which T is the absolute temperature of the elastic fluid, and c the average velocity of vibration of the molecule, it follows that at 1000 degrees F. the velocity of the molecules in the air is $\sqrt{\frac{1000 + 460}{70 + 460}}$, or 1.66 times as great as it is at room temperature. Combustion is quickened at an even higher rate, probably, because both the velocity of vibration and the number of impacts per second are increased with temperature. If burner design is the same for cold air and for highly preheated air, the flame becomes shorter and shorter, and finally becomes invisible. The shortening of the flame can, and frequently does, result in local overheating. In some cases unpleasant surprises have occurred after the installation of recuperators. The charge was almost melted near the burners while parts at some distance from the burners did not come up to the heat in the desired time. This statement is not meant to detract from the value of recuperation, but it is meant to forestall thoughtless installations and to encourage correct equipment for combustion and for circulation of flue-gas in conjunction with the recuperator.

Cases are on record in which the recuperators were gradually filled with soot and with dust given off by the charge. The recuperator material should be such that it is not attacked chemically by the dust or vapors which are given off by the charge. Furthermore, provision must be made to clean the flue-gas passages of the recuperator without much trouble. Otherwise, they may become so clogged as to become ineffective and a detriment to the operation of the furnace.

Item 4 can readily be determined. Fig. 1, shown earlier in the paper, furnishes that information. In connection with items 1 and 2, it determines the yearly saving in dollars. Against it are pitted items

5, 6 and 7. Item 5 depends largely upon the temperature potential between the products of combustion and the preheated air. If that difference is to vanish, the recuperator would have to be infinitely large. Fig. 2 explains the relation between the size of recuperator and the temperature potential for a given weight of fuel gas and air. The abscissæ represent heat-exchanging surface per unit gas flow, while the ordinates are temperatures of products of combustion or of air. Several values were used for the extent of the heat-exchanging surface, and the corresponding temperature potentials were plotted, a straight-line temperature distribution being used as a first approximation. For this approximation use was made of the formula, $\frac{A}{W} = \frac{C_a}{K}\left(\frac{T}{\triangle T} - 1\right)$, in which A represents heat-exchanging surface; W represents air flow in pounds per hour; C_a represents specific heat of air; K represents heat-transfer coefficient from products of combustion to air; T represents temperature to which air is preheated; and $\triangle T$ represents the temperature difference between products of combustion and preheated air. An examination of the equation and of the illustration brings out the fact that moderate amounts of preheat can be obtained with small heat-exchanging surface, but that closer and closer approach to the temperature of the products of combustion calls for disproportionately large surfaces; and, since the cost of a recuperator is a function of the heat-exchanging surface, it becomes evident that the obtaining of high preheat costs money.

From curves given in "Industrial Furnaces," volume 1, which are here reprinted as Fig. 1 and 3, it follows that with a flue-gas temperature of 2220 degrees F. and with oil fuel, an air temperature of 1800 degrees F. produces a saving of 41 per cent., while an air temperature of 1000 degrees F. results in a saving of 27 per cent. At the same time the high preheat calls for three times the heating surface. In order to increase the saving 50 per cent., we must increase the cost 200 per cent., unless we can either increase the heat-transfer coefficient, or make the recuperator of a very inexpensive material. It may be stated here that the material of the recuperator has a great influence on its cost; steel, cast-iron, and tile are cheap, while alloys and protected steel are expensive. This will be discussed later.

The heating surface, which affects the cost of the recuperator, piping, etc., determines the investment required, and the fixed charges.

Item 6 (repairs and maintenance) is of extreme importance. It contains several uncertain factors. Among them are furnace design

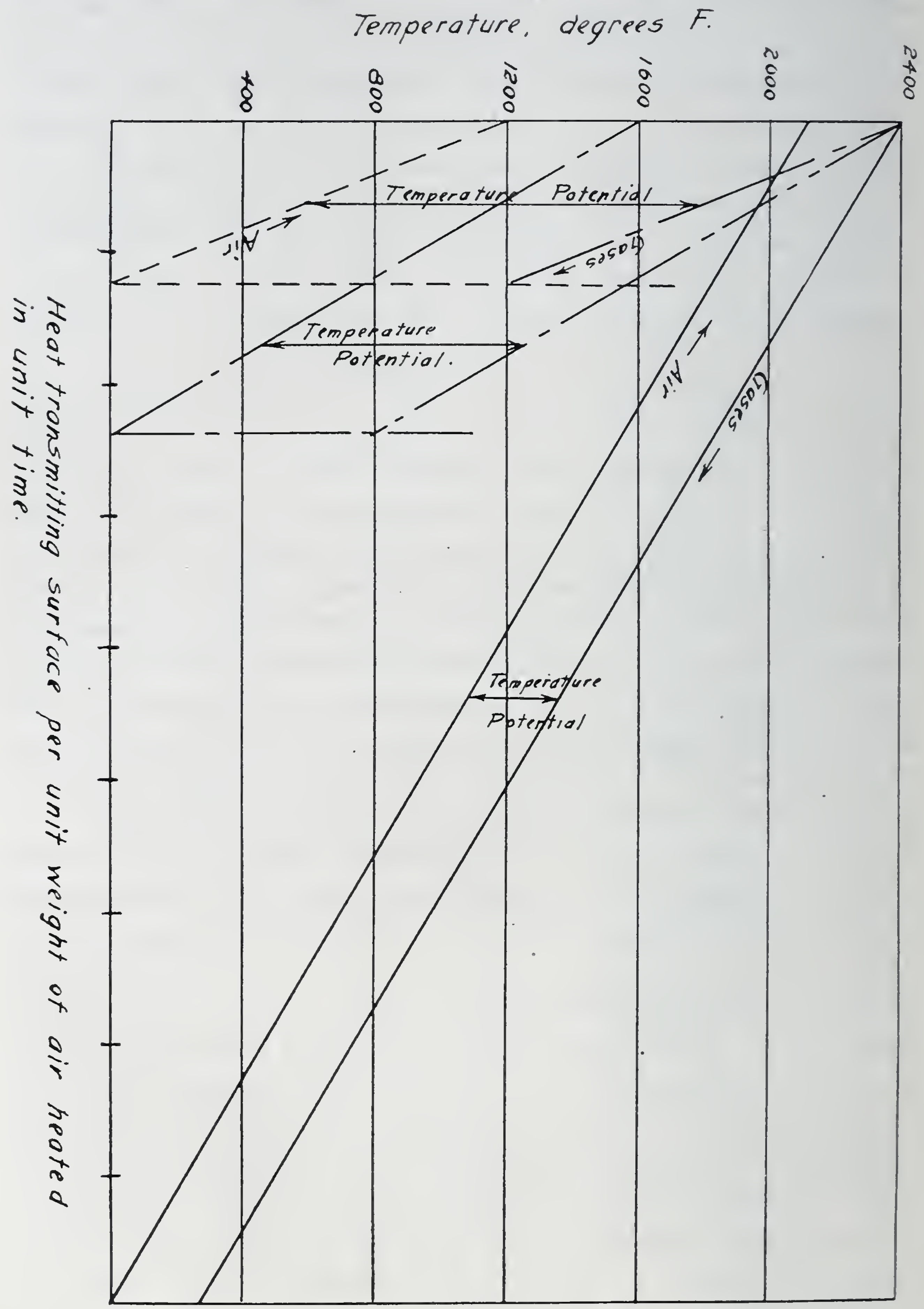

Fig. 2. Relation Between Heat-Transmitting Surface and Temperature Potential.

and furnace operation. In many furnaces, flames—that is, burning and luminous gases—enter the recuperator, exerting a blow-torch action which is very destructive. In the recuperators which are supplied with blower air, failure of the power supply stops the air flow,

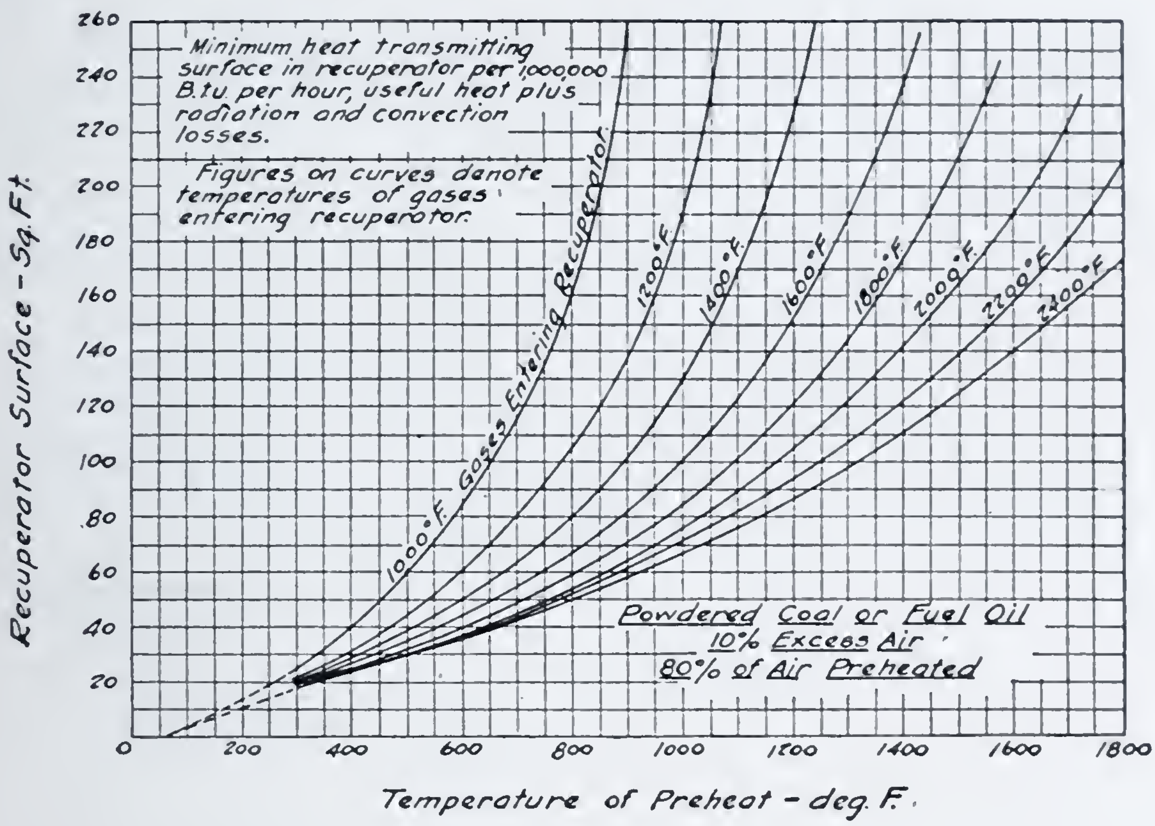

Fig. 3. Recuperator Surface Required for Furnaces Using Powdered Coal or Fuel-Oil.

while the stack keeps on pulling hot products of combustion through the recuperator, whereby the latter is overheated and burned out or cracked. In tile recuperators, frequent cooling down and starting tend to produce cracks. Several different methods have been used to prevent this trouble.

In metallic recuperators, high furnace temperatures coupled with high preheat are quite destructive. In each case, a careful survey of the probable cost of maintenance and repairs is desirable, due consideration being paid to all influences. Such a survey is impossible in stock furnaces; but, in any event, before a recuperator is installed, it is advisable to inquire carefully into the probable cost of repairs and maintenance, and to obtain some sort of guarantee on this point. In some metallic recuperators the cost of power for blowing the air through the recuperator is quite an item and must be considered in the cost of operation.

It would be extremely interesting to have a list of recuperators of various makes, together with tests on coefficients of heat transfer, space requirements, first cost, and cost of repair and maintenance, but this information is not easily obtained. Manufacturers are loath to have comparative data published. And when it comes to heat-transfer data, the manufacturers themselves are not so sure about them. For that reason I will switch into the realm of applied science and spend some time on the theory of heat transfer in recuperators.

Fig. 4 represents an element; that is, one small part of an ideal recuperator. The problem is how to get as much of the heat of the

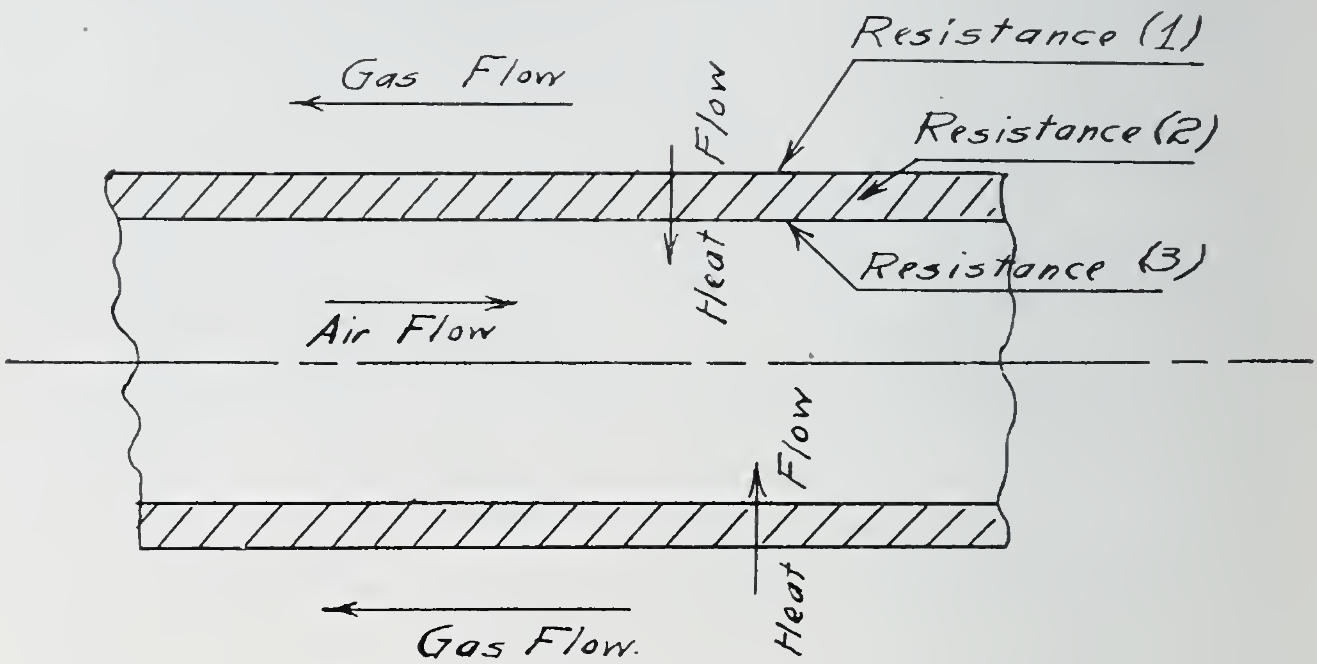

Fig. 4. Element of an Ideal Recuperator.

products of combustion as possible to the cold air through a given heat-exchanging area. In this problem we find that the heat transfer occurs against three resistances in series. The first resistance occurs between the hot gases and the wall; the second one lies between one side of the wall and the other; and the third one between the other side of the wall and the cold air. The formula for the heat transfer is $\frac{D}{R_1 + R_2 + R_3}$, in which D represents the total difference in temperature, R_1 represents the first resistance, R_2 the second resistance, and R_3 the third resistance.

On the hot side, heat transfer occurs by radiation and by convection. These two heat-transferring agencies are somewhat in conflict with each other. In order to get the maximum heat transfer by

convection, we need a high velocity of flow, and a long path. For maximum heat transfer by radiation we need, on the other hand, a deep, thick layer of gas, and this can not be obtained unless the gases move at low velocity. Since radiation increases very rapidly with the absolute temperature, it is good engineering to depend upon radiation at the hot end of the recuperator, and to depend upon convection near the cold end. Both of these statements refer to the side on which the products of combustion move. It is not advisable to go deeply into the laws of gaseous radiation in the present paper, because these laws have been set forth in great detail in other publications, and it would be a waste of time, print, and paper to repeat them here.

On the cold side (the side where the cold air moves) we can not depend upon radiation to the same extent as on the hot side—first, because the air is cold, and therefore does not absorb radiant heat; and, second, because air does not contain sufficient quantities of those gases which radiate. This latter statement refers to water vapor and carbon dioxid. In consequence, it is good practice to provide on the air side a long path through which the air flows at high velocity. In carrying out this apparently sound law of engineering, we meet two limitations. If we make the path too long, and make the velocity of the air too high, we soon build up an enormous pressure drop through the recuperator. The consequence of the pressure drop presents several difficulties:

1. The power requirement goes up by leaps and bounds.

2. The slightest crack or hole in the heat-exchanging wall causes a great loss of cold air into the flue-gas duct, with the attendant troubles which were mentioned in the early part of the paper.

3. It is almost impossible to increase air flow later on, because even a slight increase in the air flow would cause the pressure drop to build up rapidly beyond the capacity of the air-moving apparatus.

Finally, increase of the velocity and lengthening of the path affect only one of the three resistances—namely, R_3. Unless the other two resistances are quite low, further reduction in the R_3 will affect the overall heat transfer only to a very slight extent.

In order to make R_2 (the temperature drop through the heat-exchanging wall) quite small, the walls should be of high-conductivity

or low-resistance material. Foremost among the above materials are the metals. Next in line come materials such as silicon carbid, which is now known under the trade name of "carborundum" or "crystolon." At the end of the line come the strictly refractory materials, such as fire-clay and silica. The difficulty with the refractory materials lies in their low tensile strength and their tendency to crack when exposed to temperature changes. The theory of the cracking of recuperator materials is likewise explained in volume 1 of "Industrial Furnaces," and need not be repeated here. The following should, however, be noted. For certain classes of service—for instance, for use as tank blocks in glass-melting furnaces—refractory materials have been developed which will withstand very great temperature differences without cracking. It is advisable to use a similar material in recuperators. It is a well-known fact that tank blocks have a very high conductivity and slight tendency to spall.

An additional difficulty with refractory materials for recuperator service lies in the joints between the various elements from which the recuperator is built up. Refractory materials always warp more or less in the burning process, and for that reason, if they are used as delivered, are never tight where one block fits against the next one. For that reason, recuperator tiles are usually made overlapping so that, if there is not an absolutely tight joint, there is at least a labyrinth packing which offers considerable resistance to the passage of the air. Another and better solution to this problem is the grinding of the surface of the burned tiles so that all joints fit perfectly. Furthermore, recuperator tiles are commonly so made and laid, that gravity tends to seal the joints. Finally, they are usually so designed that expansion of the recuperator as a whole can occur without either strain of the individual block, or any opening up of cracks. It may also be possible, in laying recuperator tiles into place, to use a furnace cement, or a viscous substance which will keep the joints well sealed at all times.

During recent years, considerable progress has been made in the construction of the heat-transmitting wall. In metallic recuperators, heat-resisting alloys have been introduced. It is now possible to obtain heat-resisting alloys in sheets as thin as 1/30 of an inch. It is also possible to weld these alloys, to produce a homogeneous and jointless recuperator surface of very high heat-transmitting quality. Methods

have also been worked out for taking ordinary steel piping, sheeting, or castings, and applying a coating resistant to heat and oxidation, such as aluminum oxid or chromium. The upshot of the improvement is that in recent years metallic recuperators have been used to a very great extent.

On the other hand, great improvements have also been made in tile recuperators. Some of these were mentioned above. Another improvement consists in so arranging the tiles that approximately equal pressures exist at both sides of the heat-transmitting wall. If such pressure equalization can be obtained, cracks, if they should develop, would do little or no harm, because there would be no tendency for the two gaseous streams to intermingle. Equalization of pressure on the two sides is based upon the use of low velocities on both sides of the heat-transmitting wall, because high velocities always mean a pressure drop.

In the counter-flow system of recuperation, which is commonly employed in tile recuperators, the pressure drops are opposed; that is, high pressure on the flue-gas side occurs where the low pressure exists on the air side. This difficulty has been overcome to a certain extent by the use of buoyancy as the moving agent on the air side. If, in a recuperator which lies far enough below the furnace, a small restriction is placed at the entrance to the air, and also a slight restriction at the top, then a slight vacuum can exist all the way through the recuperator except at the top where there might be a slight pressure. On the gas side we may have a slight pressure at the top, coming from the furnace pressure, and a slight vacuum at the bottom, due to the effect of the stack.

The question of the overall coefficient of heat transfer is an interesting one. Recuperators are commonly figured with an overall coefficient of 2.5 B.t.u. for each square foot per hour per degree difference in temperature between air and waste gas. Claims have recently been made that overall coefficients almost twice as great have been obtained, and some of these claims have been made for tile recuperators. It is therefore advisable to review briefly the possibilities of the transfer coefficient. On the flue-gas side we may take a gas layer one foot thick. Its radiation in B.t.u. per square foot per hour at 2200 degrees F. would be 7. At 1300 degrees the coefficient would be 4, so that we may take an average coefficient of 5. Due to convec-

tion we may have a coefficient of 2, so that the total coefficient on the gas side would be 5 + 2, or 7. Turning to the air side, and allowing a pressure drop of 0.1 of an inch through the recuperator (See "Industrial Furnaces," volume 1, page 109), we find a coefficient of 3½. If, on the other hand, we are willing to allow a pressure drop of 0.6 of an inch through the recuperator we find a coefficient of 7. For tile recuperators so high a pressure drop is out of the question, so we will take a coefficient of 3½. If the heat-transmitting wall has no resistance whatsoever, then the coefficient would be $\dfrac{1}{\dfrac{1}{7}+\dfrac{1}{3.5}} = \dfrac{7}{3} = 2\ 1/3.$

In a recuperator with a permissible pressure drop of 0.6, the coefficient would be $\dfrac{1}{\dfrac{1}{7}+\dfrac{1}{7}} = 3½.$

The coefficient can be increased by having the gases of the hot side give up heat not only to the heat-transmitting wall, but also to the other three walls of the duct, and then having the solid radiation from these walls to the heat-exchanging wall assist in the heat transfer; but, even if that is done, it seems doubtful whether the coefficient can ever be raised much above 2½, even if we use refractory materials with an exceedingly high conductivity. It would be desirable to have test data on recuperators made with these alleged high heat-transfer coefficients. The chances are that, where tile recuperators are used in connection with producer gas, the combustion in the furnace has been very slow, similar to that obtained with regenerators, and that combustion extends all the way through the furnace into the recuperator. If combustion extends away down through the ducts of the recuperator, then it is quite possible to find high apparent heat-transfer coefficients, but it must be repeated that these high coefficients are apparent only and not real. "After burning" in the recuperator always raises the coefficient if we base its value upon our ordinary calculation and would have the same effect in a metal recuperator, raising its heat-transfer coefficient.

Throughout this paper the terms "counter flow" and "parallel flow" were mentioned with regard to recuperators. By counter flow is meant that the products of combustion move in one direction while the air moves in the opposite direction. By parallel flow we mean

that both the air and the products of combustion move in the same direction. Half way between the two types lies a type of flow which is known as "cross flow." The counter-flow principle allows the obtaining of a very high preheat if enough area is provided, whereas the parallel-flow system allows the hottest products of combustion and the coldest air to wash the surface of the heat-exchanging wall at the same spot where the products of combustion enter. These explanations will be used in the latter part of the paper.

In an earlier part of the paper mention was made of the fact that the use of preheated air has an effect upon the combustion and that care must be taken to change the burners and the passage of the gases around, if we wish to control combustion. The following is also of importance. Oil burners and gas burners, while rated in the capacity of so much oil per minute and so many cubic feet of gas per minute, are, as a rule, limited by the quantity of air which they can pass. It should be kept in mind that highly preheated air takes up very much more volume than cold air, and that in consequence, with a burner which was designed for cold air, it may be impossible to pass enough preheated air for combustion.

In the use of recuperators, attention should be paid to the effect which highly preheated air may have upon oil or tar. Both fluids break down at high temperatures, and, if highly preheated air flows through a pipe which surrounds an oil pipe or a tar pipe in a burner, decomposition of the slowly flowing oil may easily occur, with the resultant formation of coke which becomes so hard that it can be removed only with a chisel.

After this general description of the underlying principles of recuperators, and of the difficulties which must be overcome in their design, construction, and operation, it will pay to study the various makes of recuperators which are now on the American market. In this description it should be understood that the list of recuperators is by no means complete, because some plants have installed in their furnaces recuperators of their own design and construction. These are not mentioned in the list which will now be given.

It should be noted that the recuperators are arranged alphabetically. The result of this arrangement is that tile and metallic recuperators are mixed indiscriminately.

The "Amco" recuperator, furnished by the Amsler-Morton

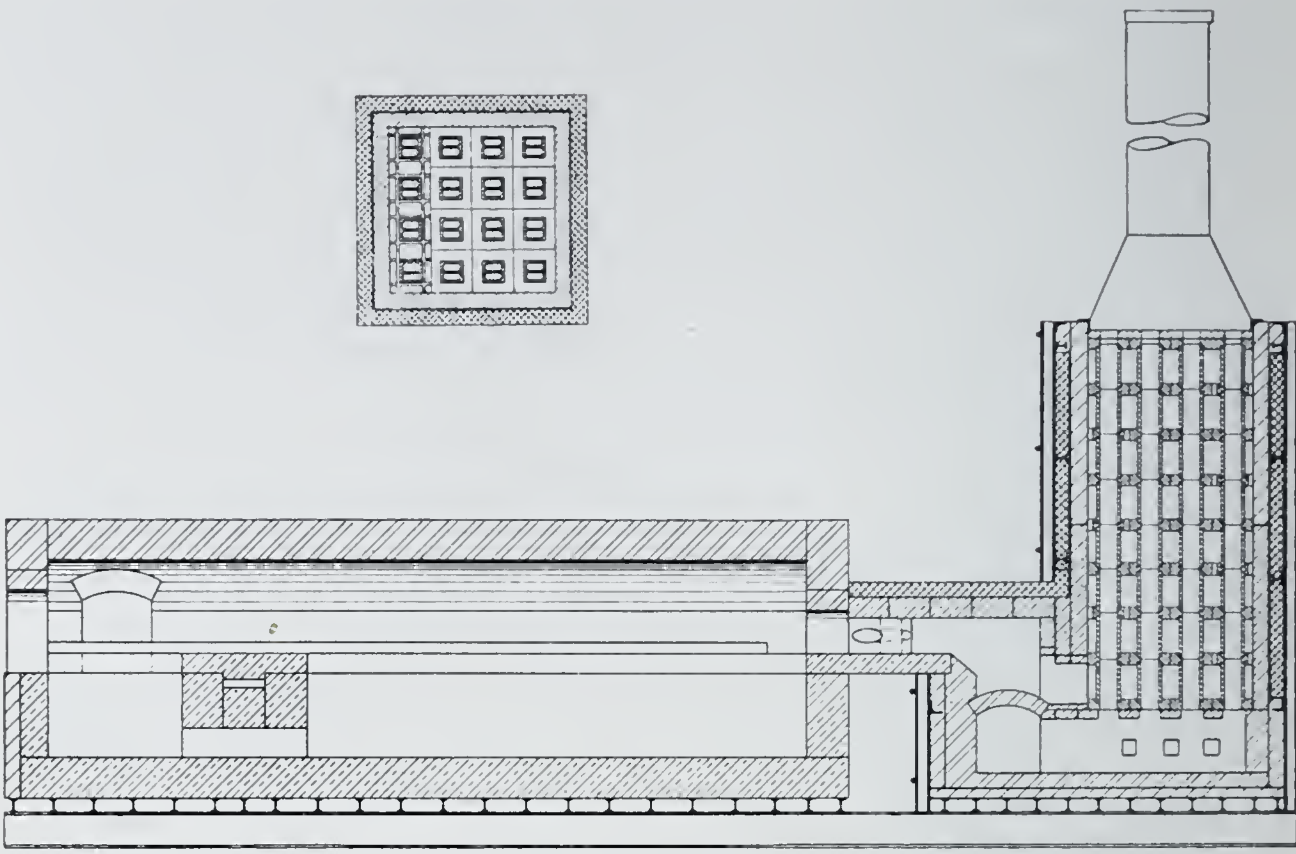

Fig. 5. Amsler-Morton Chimney-Type Recuperator.

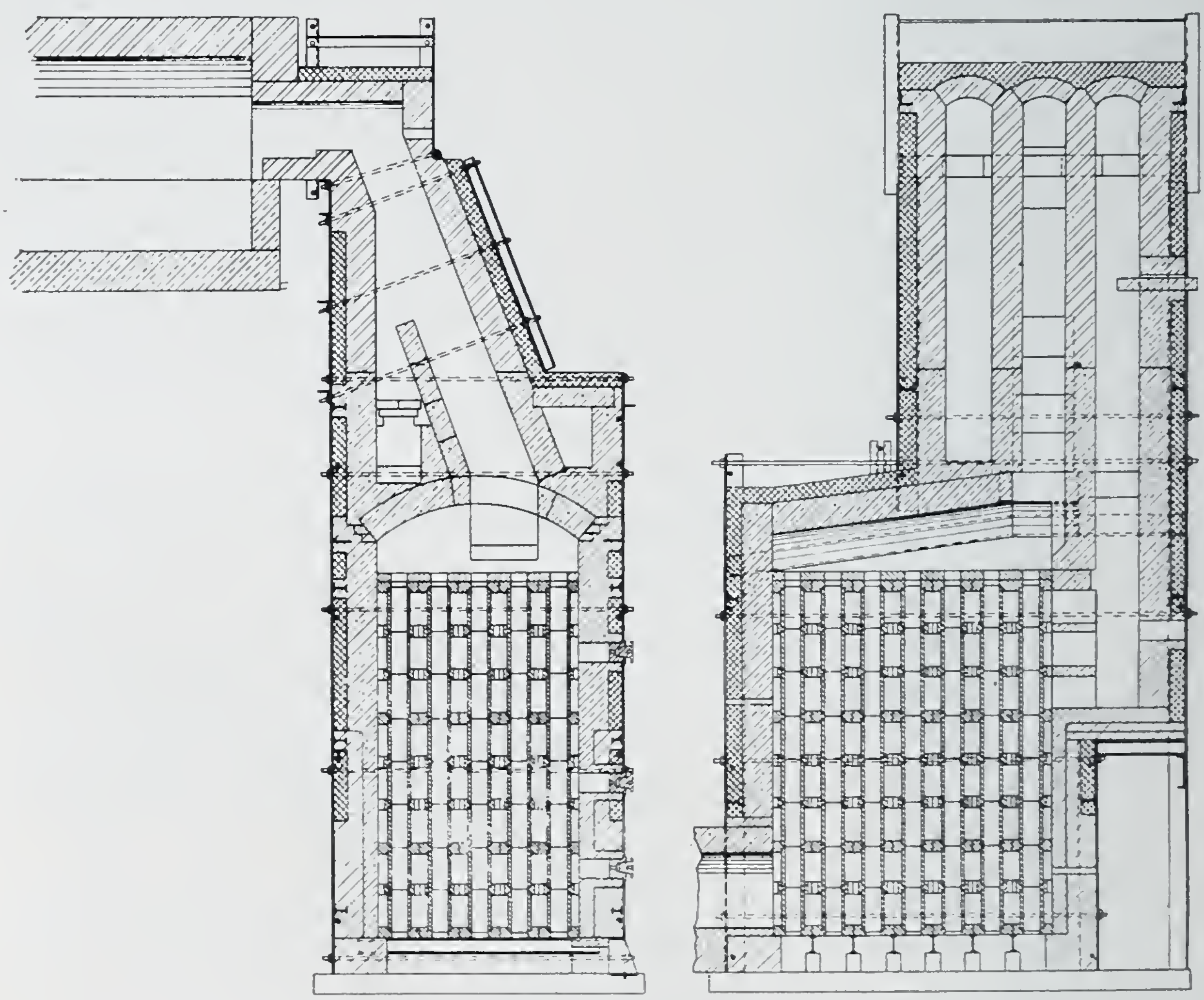

Fig. 6. Amsler-Morton Recuperator for Location below the Furnace
(United States Patent 1,587,171; others pending).

Company and by the Rust Engineering Company, is shown in Fig. 5, which shows the type of recuperator which is set under a furnace; and in Fig. 6, which shows a chimney-type recuperator. All are of design intermediate between the cross flow and the counter flow. The tubes are of square cross-section with an intermediate dividing rib. They are made of fire-clay, and are set vertically. Cross tiles prevent them from moving sidewise, and also guide the air or gases. In the chimney-type recuperator, the gases flow directly upward through the inside of the tubes, while the gases pass downward and

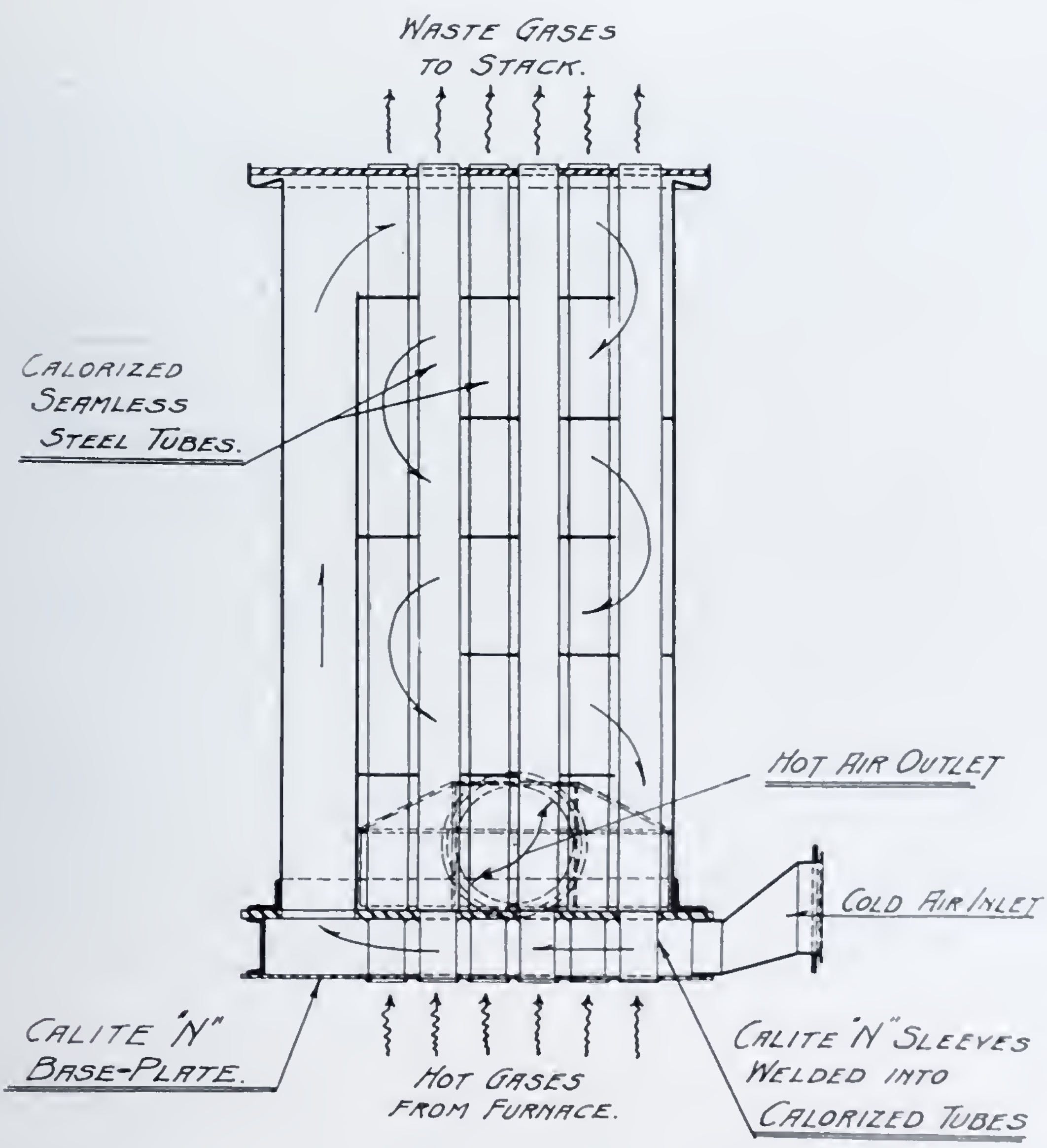

Fig. 7. Standard "Calco" Recuperator.

across the outside of the tubes in numerous passes. In the types located under the furnace this arrangement is reversed. In Fig. 5 the long, parallel gas and air passages, side by side, act as additional recuperator surface, having a high rate of heat transfer on account of the high temperature of the gases and on account of radiation from

those sides of the passages adjacent to the heat-transmitting walls. The hot gases are thereby reduced in temperature before they strike the tile recuperator tubes. The effect of the long brickwork passages is thus to protect the tiles from excessive temperatures.

The "Calco" recuperator is of the stack type, as shown in Fig. 7. Round tubes of calorized (aluminum coated) steel are used. The gases pass upward through the inside of the tubes. The entering air circulates around the bottom of the tubes, then ascends through a

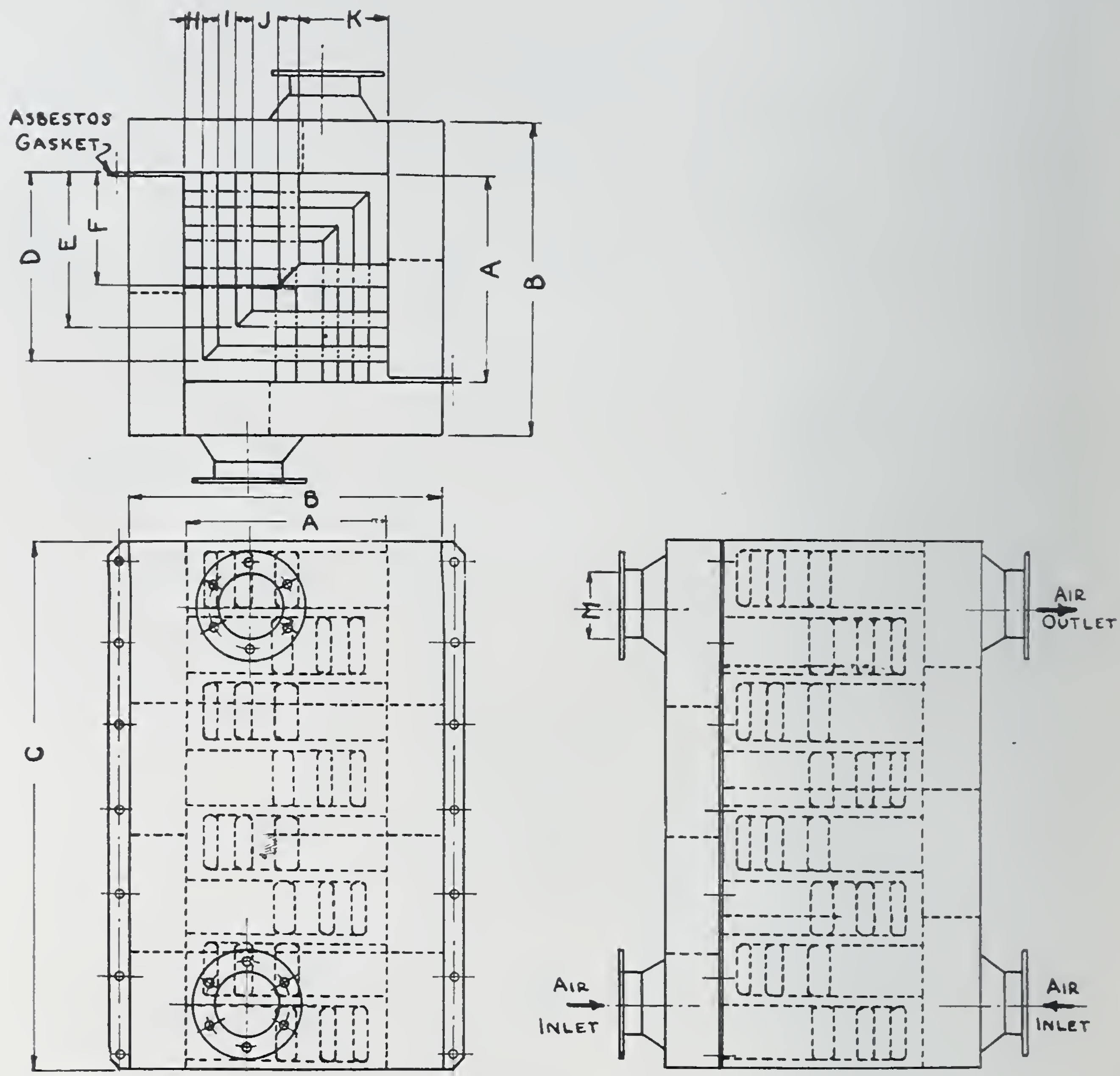

Fig. 8. Duraloy Vertical-Flow Recuperator.

jacket space surrounding the recuperator, and flows down along the tubes, making several passes across them as it descends, as shown in the figure. For high temperatures, the lower ends of the tubes as well as the base-plate are made of "Nichrome." All joints are welded.

A bellows expansion joint is provided at the top of the recuperator. The advantages claimed for this recuperator are efficient heat transfer (due to the use of metallic walls and to counter-flow circulation throughout the greater part of the length); protection of the hot ends of the tubes by circulation of cold air around them; practically leak-proof construction due to the use of welded joints; compactness (the unit is self contained and needs no brick casing); and almost complete elimination of heat loss by radiation from the walls, due to the air-jacketing feature.

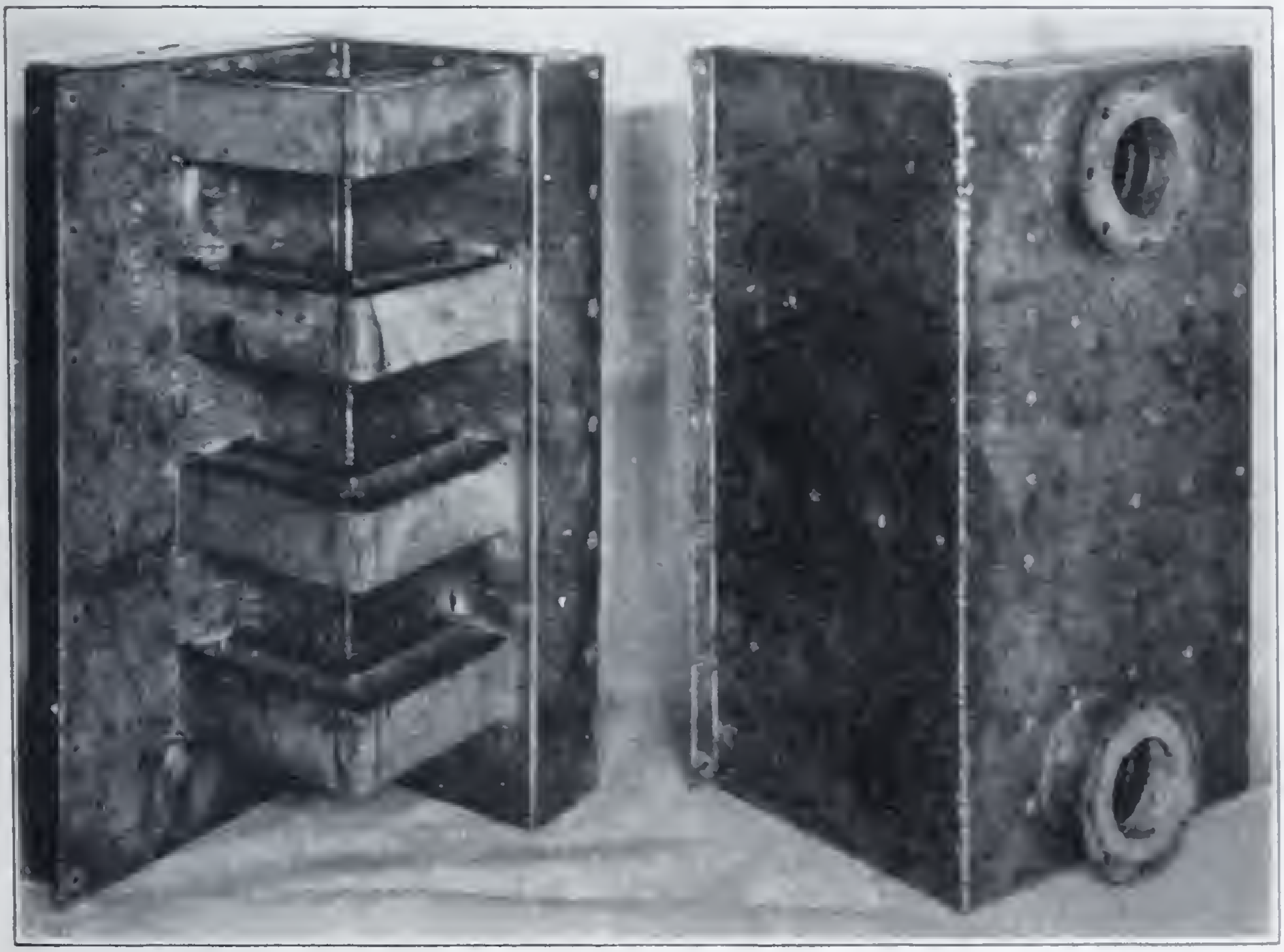

Fig. 9. Exterior and Interior Views of Vertical-Flow Recuperator.

The Duraloy Company builds a stack-type metallic recuperator shown diagrammatically in Fig. 8. Interior and exterior views are shown in Fig. 9. The tubes and plates in contact with the gases are made of rolled "Duraloy," a chrome-iron alloy. The gases pass vertically upward, while the air enters at the bottom, at opposite sides, and passes alternately through the bent, horizontal tubes from side to side, until it reaches the top. The recuperator is thus of a combination parallel-flow and counter-flow type. The two adjacent sides of the

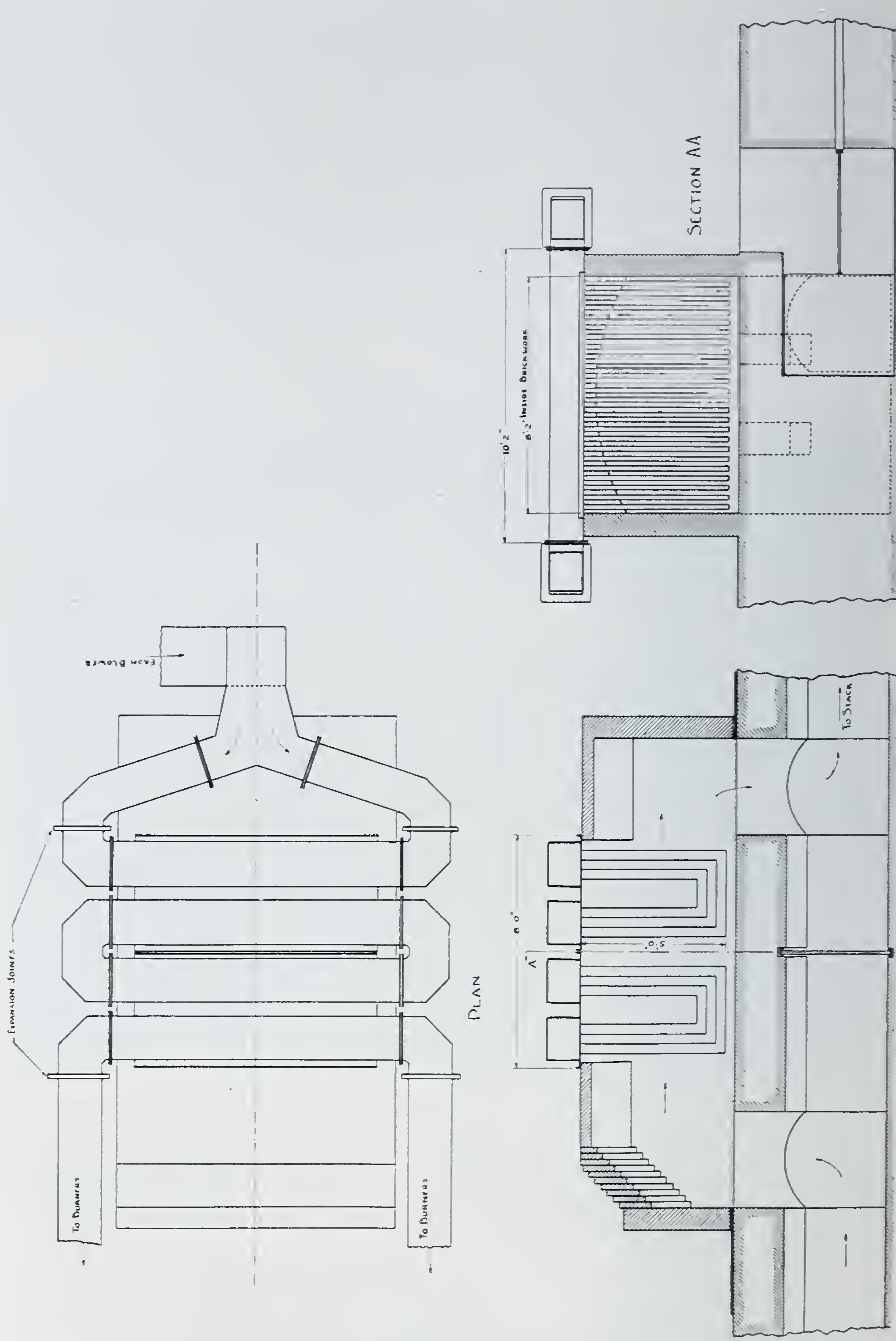

Fig. 10. Duraloy Horizontal-Flow Recuperator.

hollow square (plan view), with the attached tubes, form a unit. Each recuperator thus has two units which are independent except where

bolted together at the sides. The advantages claimed for this recuperator are high rate of heat transfer due to the use of metal tubes; freedom of expansion together with flexibility of tube sides, reducing the possibility of cracking; leak-proof construction, all joints being welded; and durability, due to the heat-resisting nature of the material used.

All stack-type recuperators have the advantage of being easily installed and readily accessible.

The Duraloy Company also makes, for larger furnaces, a recuperator of the hanging-loop type, as shown in Fig. 10. The gases flow horizontally past the tubes and the air passes through the tubes from one header to the other. The design is claimed to provide great freedom of expansion, together with large heating surfaces in a small space.

The "Fitch" recuperator, made by the Carborundum Company, is intermediate between the counter-flow and cross-flow types. It is

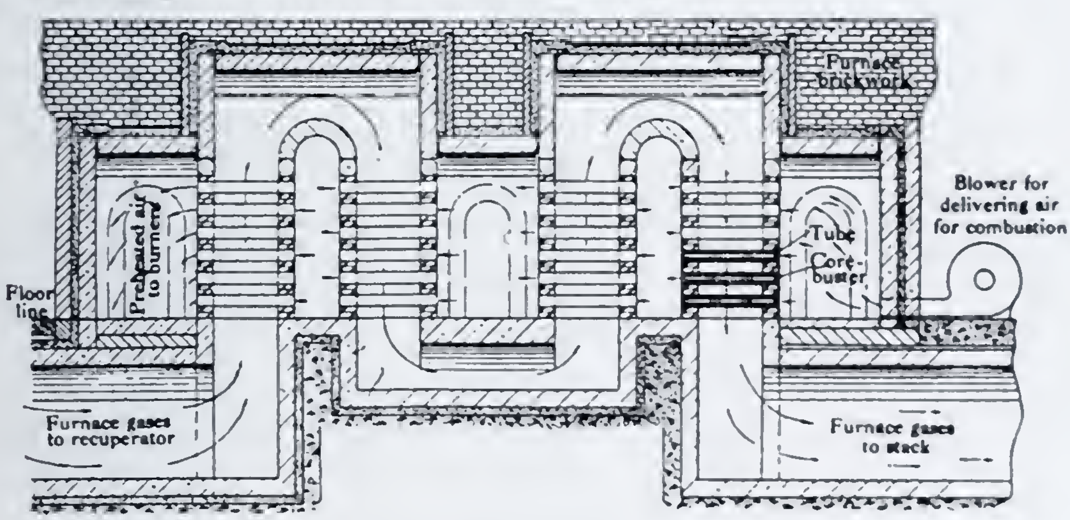

Fig. 11. Fitch Recuperator.

shown in Fig. 11. Carborundum tubes are used. The waste gases flow around the outside of the tubes, making several (usually four) passes. The air flows through the inside of the tubes, which contain "corebusters" of refractory material, held centrally in the tubes by refractory plugs. The "corebuster" is found to increase heat transfer to three times its value without the "corebuster." The joints of the ends of the tubes with the fire-brick walls of the passages are packed with refractory cement. The tubes are arranged in several (usually four) separate lengths, separated by header spaces. The doors shown at the sides of the header spaces allow a man to enter to inspect the

tubes from either end, and the alternate spaces are wide enough to allow replacement of any tube from one end. The advantages claimed are high rate of heat transfer, together with great durability and free-

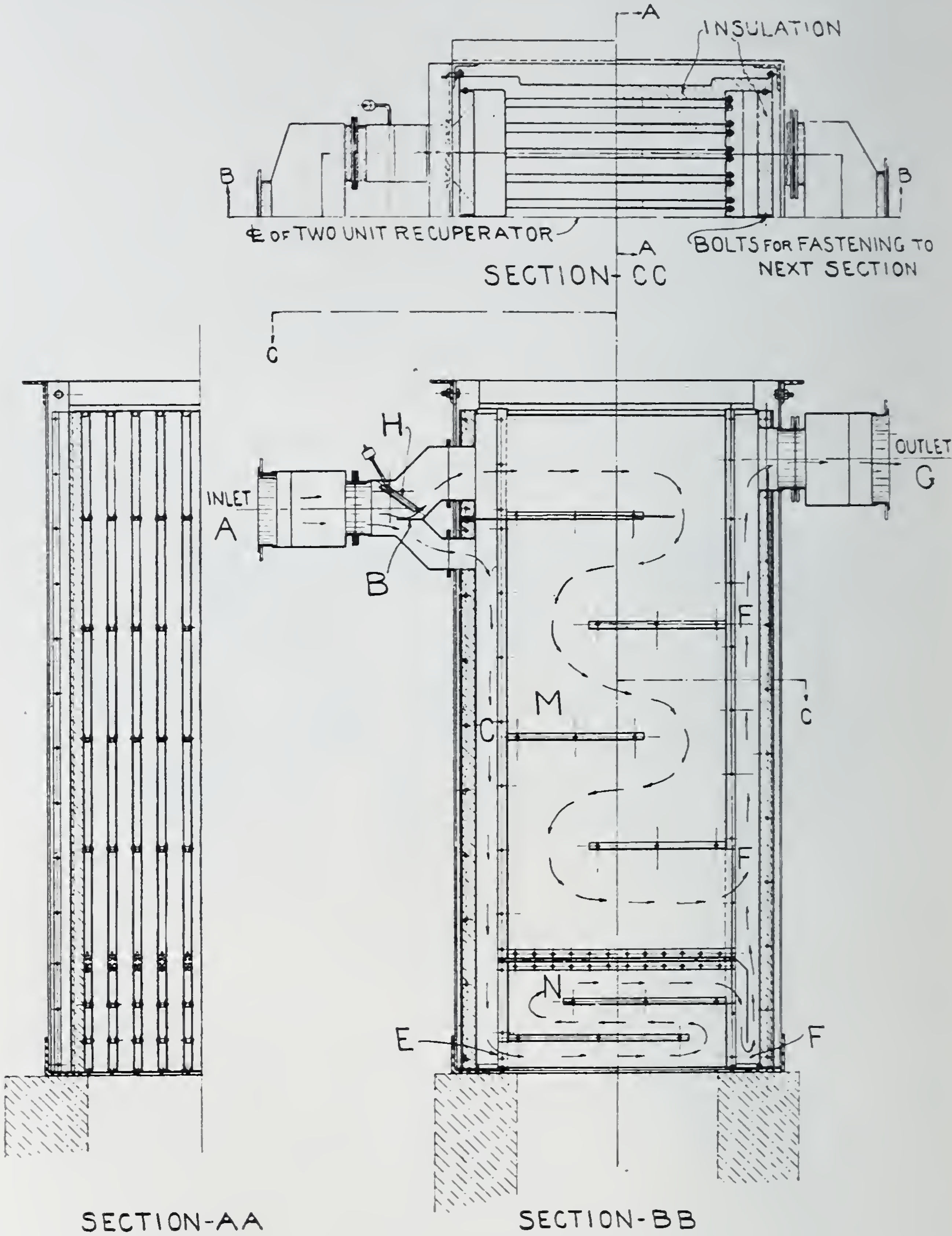

Fig. 12. Mantle Recuperator.

dom from leakage, due to the high conductivity; great mechanical strength; and resistance to deterioration of the carborundum.

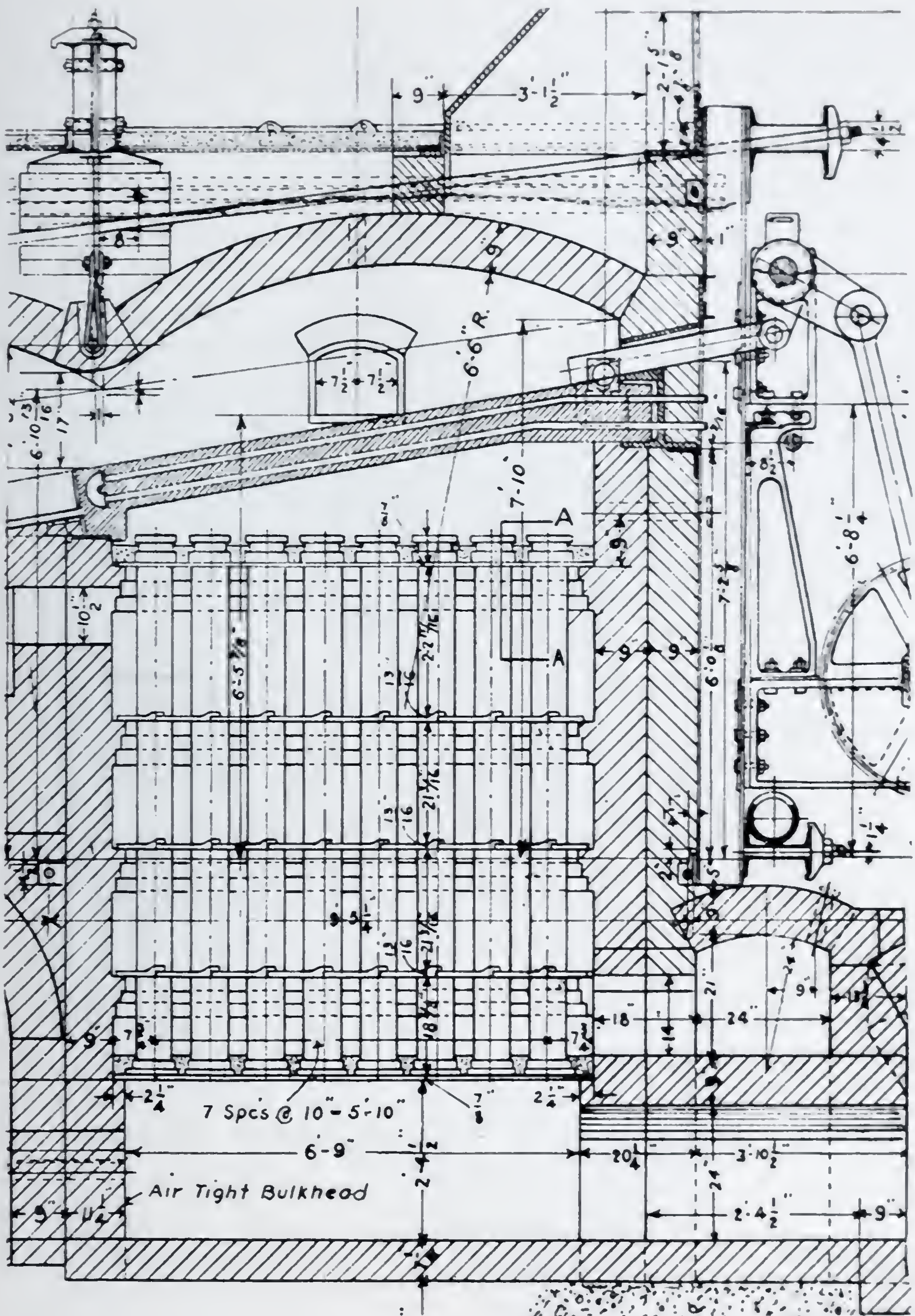

Fig. 13. Morgan Recuperator.

The Mantle recuperator, made by the Mantle Engineering Company, is shown in Fig. 12. It is a metallic flat-plate, stack-type recup-

erator, in which the waste gases pass upward in thin streams. Part of the air passes at all times across the lower ends of the separating plates, in order to prevent overheating where the hottest gases strike them. The remainder of the air, the volume of which is regulated by a damper in the inlet, passes downward and across the plates, leaves near the bottom, and passes upward to the outlet near the top. The plates are made of rolled "Ascoloy," a chrome-iron alloy. All joints are on the air side, not exposed to the hot gases, and are both riveted and welded. The advantages claimed for this recuperator are freedom of expansion, freedom from leaks, compactness, accessibility for cleaning the surfaces, and high rate of heat transmission. The recuperator is self contained, and does not require a brick setting. Structural work is provided for supporting the stack and thus preventing strain on the recuperator elements due to the stack weight.

The Morgan recuperator, furnished by the Morgan Construction Company in connection with continuous reheating furnaces, is shown in Fig. 13. The gases pass downward through cast-iron pipes, and the air flows upward along the pipes, being properly directed by openings in the cast-iron plates placed at right angles to the pipes. The joints between the tubes and the plates at the top are asbestos packed, and sand seals are provided at the bottom. The advantages of this recuperator are low cost and economy of space.

The recuperator furnished by the Smith Gas Engineering Company, shown in Fig. 14, consists of parallel box sections of cast "Thermalloy," a chrome-iron alloy. The gases pass upward outside and the air downward inside the flat tubes or boxes. A sand seal is used at the joint of the upper air manifold with the surrounding brick walls. A wire-screen baffle is arranged in the manifold to distribute the air uniformly among the various tubes. On account of using the cast sections, this recuperator is said to be able to withstand quite high temperatures. When used where the gas temperature is high, the hot ends of the tubes are filled with nickel-wire screens for the purpose of absorbing heat from the tube walls by radiation and transferring it to the air by convection, thus reducing the temperature of the tube walls.

The standard Chapman-Stein recuperator, built by the Chapman-Stein Furnace Company, is shown in Fig. 15. The tubes are built up of specially shaped fire-clay tiles, with cross tiles which hold

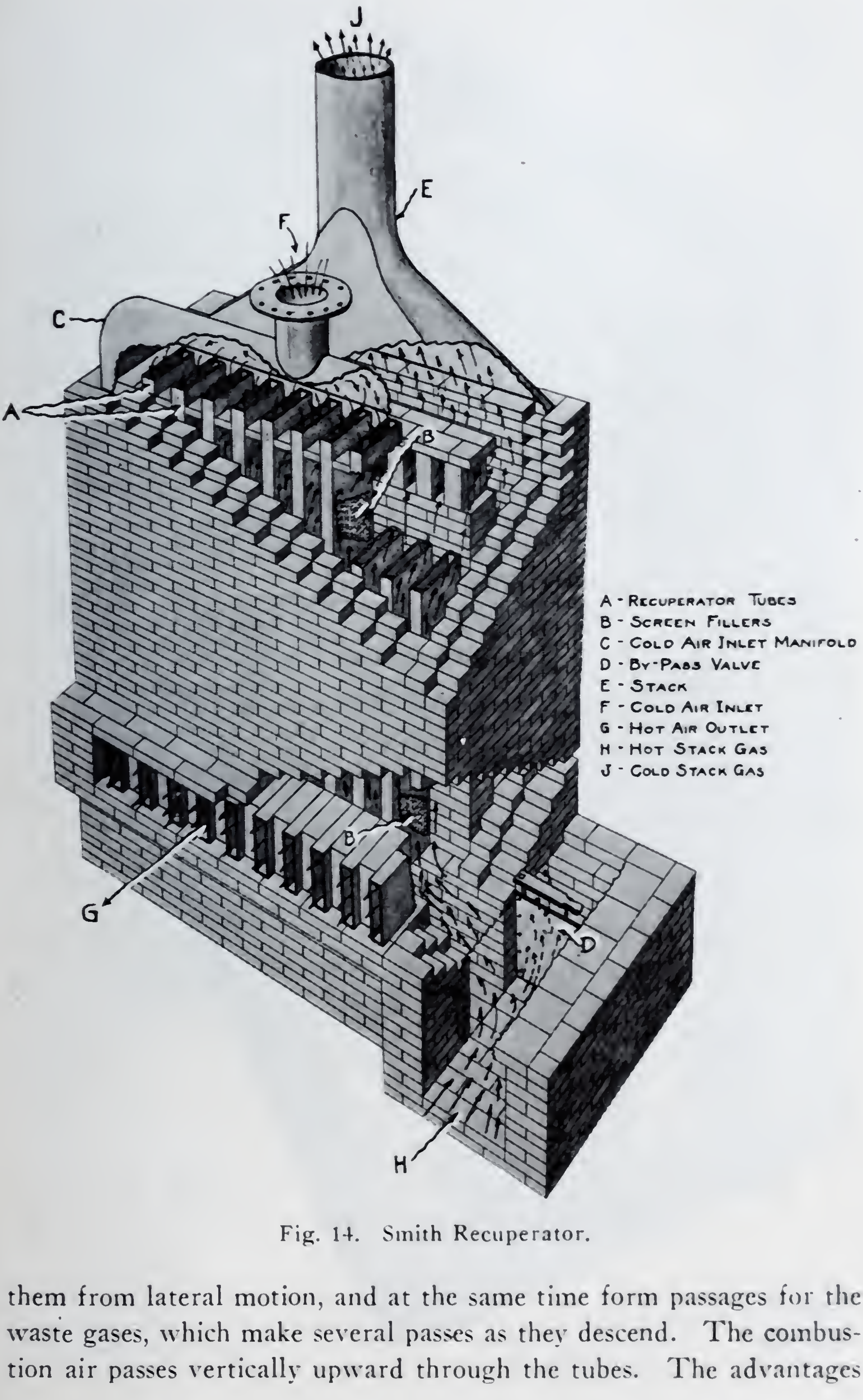

Fig. 14. Smith Recuperator.

them from lateral motion, and at the same time form passages for the waste gases, which make several passes as they descend. The combustion air passes vertically upward through the tubes. The advantages

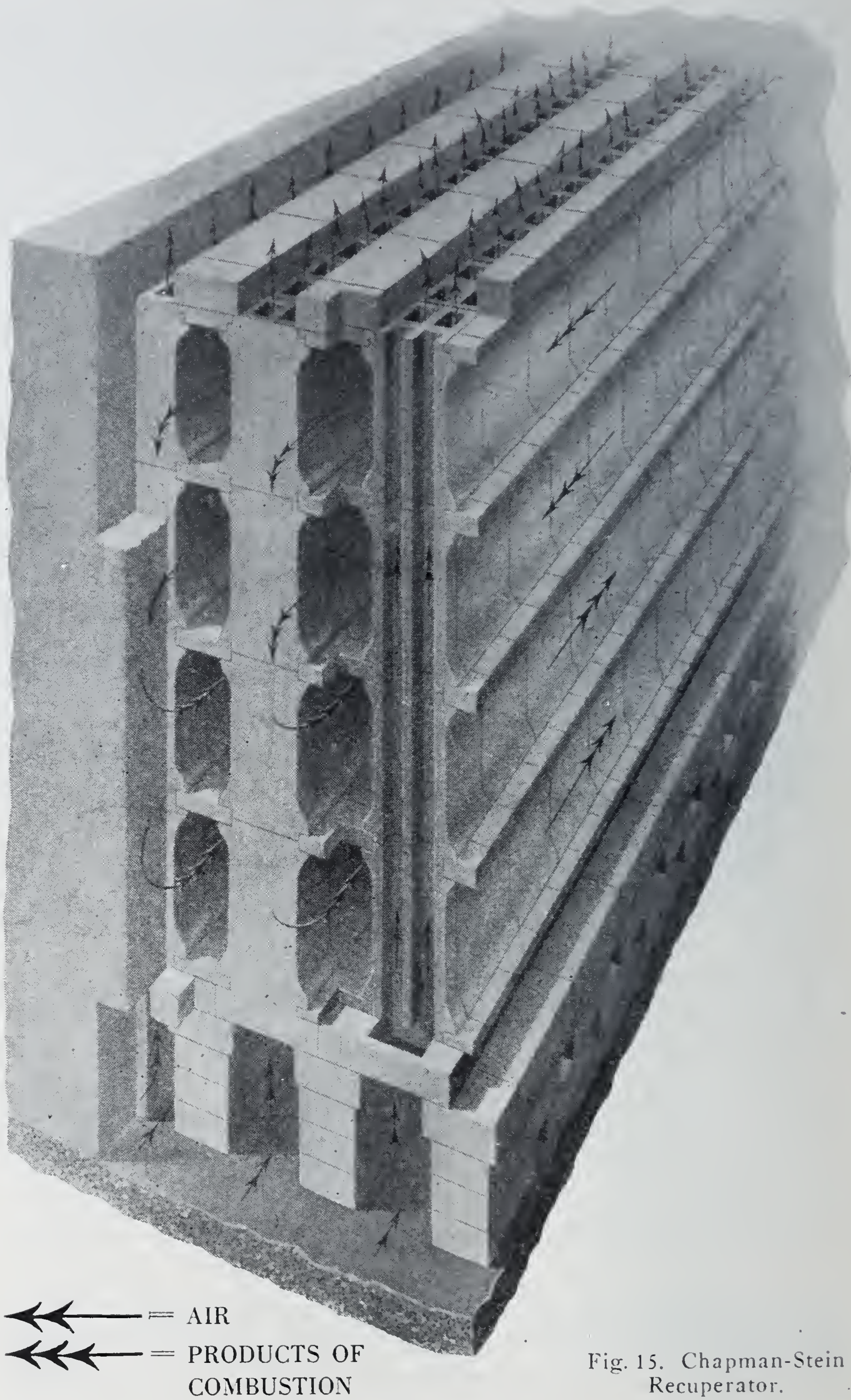

Fig. 15. Chapman-Stein Recuperator.

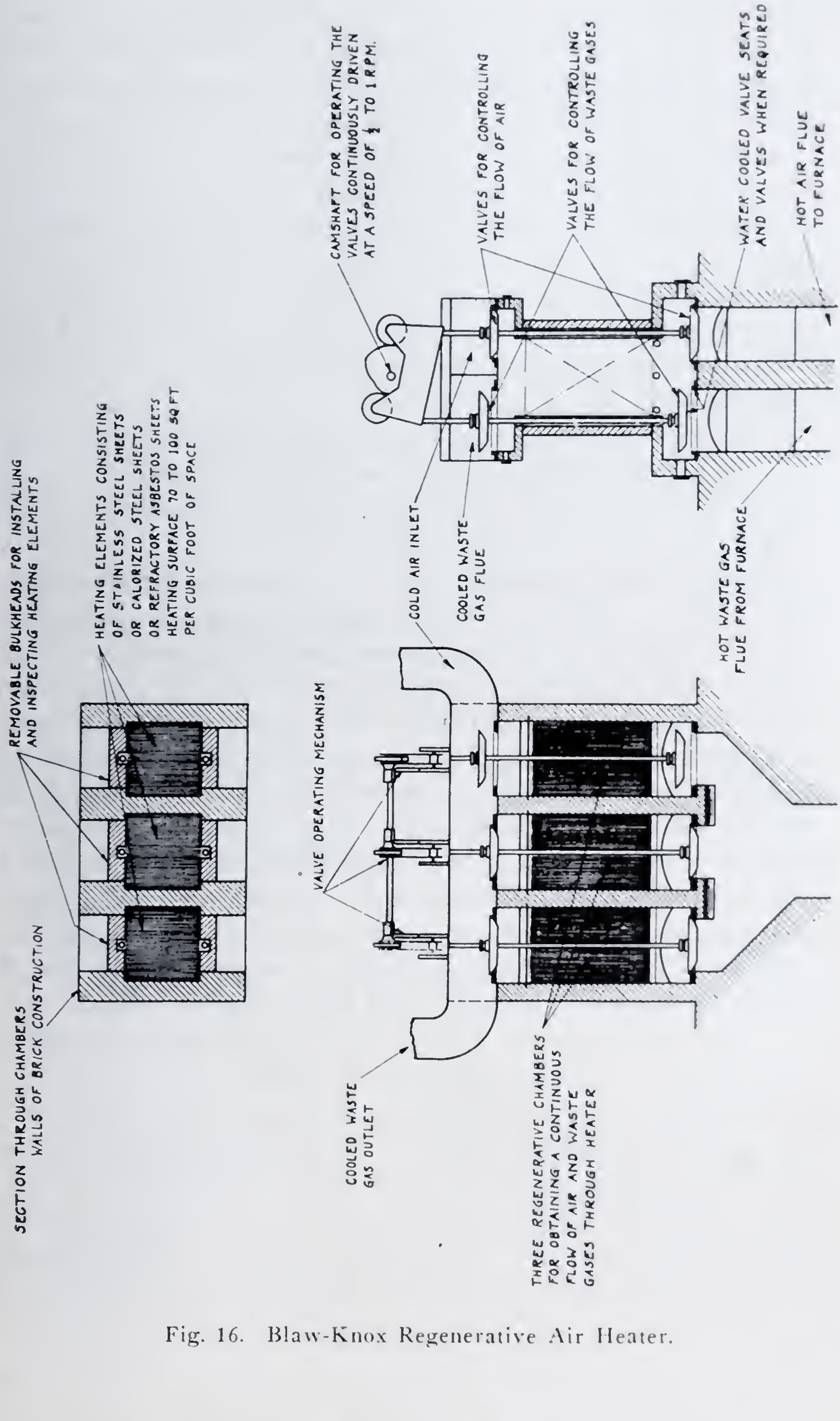

Fig. 16. Blaw-Knox Regenerative Air Heater.

claimed for the design are avoidance of leakage at the joint, because the tile are all ground true to size so that all joints fit tightly. Since all joints are horizontal, the weight of the tile tends to keep the joints closed. Each tile is a small unit and is free to expand or contract, thus reducing the tendency to crack. Pressures are balanced so that there is practically no pressure difference between the air and the gases, and hence no tendency to leak through any cracks which may occur.

The Chapman-Stein Company also builds a chimney-type or stack-type recuperator, in which the arrangement is reversed, the gas flowing upward inside the tubes, and the air flowing downward and across the tubes, making several passes.

The stack-type recuperator constructed of tile has the advantage of dispensing with a by-pass for the waste gases, since the tiles are able to withstand high temperatures if the air flow through the recuperator fails.

It may be well to mention here that a recuperator is not the only device which can furnish a steady stream of heated air. If regenerators are provided with several chambers and with valves arranged to open and close at the proper times, the air flow remains constant and in the same direction. A blast-furnace stove is one example. Another example is furnished by the Dyrssen regenerative air heater, made by the Blaw-Knox Company, and illustrated in Fig. 16. It consists of three chambers filled with thin plates spaced a short distance apart, and made of heat-resisting metal. Valves are automatically opened and closed by cams driven from a constantly running motor; these permit waste gases to flow through the chamber part of the time, and air the remainder of the time. The cam motion is such that the total flow of air from all chambers is constant at all times.

DISCUSSION

F. W. Manker:* The paper by Professor Trinks on recuperators for industrial furnaces is a very fair statement of the general factors involved in their application and the status of recuperator design as it exists to-day. It is a valuable contribution in that it focuses our attention upon the recuperator situation considered from a strictly engineering viewpoint so that the various types of recuperators may be considered for their respective merits. Although recuperation has been the subject of discussion among technical men for a long time, and although numerous companies have built recuperators of various types for years, one can not escape the impression that the amount of progress is out of proportion to the effort which has been expended in their development. This at once raises the question of the soundness of the recuperator proposition.

It would seem reasonable that after about fifteen years of effort on the part of numerous engineering organizations, a recuperator could be developed which would satisfy both the economic and the engineering requirements of the situation. The fact that the answer to these questions is still a matter for discussion, even to the point where the use of a recuperator is in many instances questioned, seems to prove that there are many factors involved which can not be isolated from the recuperator itself and which always affect the degree of satisfaction with which recuperators may be considered.

It is pointed out in Professor Trinks's paper that refractory materials have the limitations of porosity, brittleness, and low rate of heat transfer, all of which have been overcome by metal recuperators. On the other hand, metal recuperators have given trouble in distortion, oxidation, and burning out. Most recuperators which have failed, due to burning out at an excessive temperature, owe their failure entirely to the element of secondary combustion. The designer has figured a proper waste-gas temperature and has selected materials to withstand this temperature. The actual failure has caused surprise and consternation to both the designer and the furnace user. The true cause of the trouble was seldom recognized. Designers are now beginning to show a better appreciation of correct combustion. This is evidenced by fuel controls of various types, and apparatus to secure

*Vice-President, Surface Combustion Co., New York.

the correct ratio of fuel and air. It is important to remember that a correct fuel-air ratio does not mean that secondary combustion is certain to be eliminated. We have shown by test that correct ratios of gas and air have traveled in separate strata of gas and air a distance of 40 feet from the fuel inlet ports without appreciable mixing. In other words, the fuel, if not intimately mixed with air before entering the furnace, can very readily pass through the furnace and into the recuperators before there is any mixing tendency to cause combustion of the gas which is in strata. As soon as the fuel hits the recuperator it is broken up and mixed with the air and, naturally, complete combustion occurs there.

A by-product of mixing the fuel and air before they enter the combustion chamber of the furnace is an increase in the heating rate due to the higher rate of heat liberation which results from combustion being complete in a much shorter time. This produces greater rates of output in the furnace than would normally be expected.

If it were conceded that recuperators should be applied to recover the heat from the waste gases as the only consideration, then it is obvious that their desirability can be limited by two considerations of design. First, the furnace itself can be designed so that the waste gases are reduced to a very low temperature and give up their heat directly to the work; second, the type of combustion can be developed which will produce the maximum rate of heat transfer in the shortest time. I have in mind a furnace in the Cleveland district which was heating four by four billets for a rod-mill operation. It had a production of about seven tons an hour and was fired with coke-oven gas. The billets were cold as they entered the furnace and were discharged at about 2200 degrees F. In traveling 40 feet from the burners to the discharge end of the furnace, when operating under the above conditions, the normal waste-gas temperature averaged 1560 degrees F.

A re-design of the combustion chamber, and a change in the method of heat application and of firing equipment, which involved the introduction of an explosive gas-air mixture, enabled the mill to increase the output of the furnace to 12 tons an hour. The most remarkable effect was that the temperature of the gas at the downtake or charging end of the furnace dropped to 1100 degrees F. These results indicated very definitely the factors of reduction in

stratification and increase in rate of heat liberated as it affected the furnace efficiency and the waste-gas temperature.

It is my feeling that the use of recuperators should be considered:

1. As a necessity which exists in those instances where the flame temperature of the fuel used is relatively low and where the temperature of the heating operation is relatively high.

2. Where the design factors and the operation of the process prevent a furnace construction which will secure a low flue-gas discharge temperature from the furnace.

3. Where a relatively high fuel cost will justify the recuperator investment.

4. Where there is a high load-factor of operation.

From the standpoint of recuperator design it seems obvious that the improvements that are being made in the use of metallic recuperators will render tile construction obsolete in the future. This statement is made purely from commercial reasons. It seems fairly obvious that the tile recuperator, which occupies a large volume and which usually requires very expensive excavations, foundations, and a considerable expenditure for additional side wall and steel in the furnace construction itself, which will total an investment that is in many instances twice the actual value of the recuperator material itself, is uneconomical. It is evident that a metal recuperator which has an installation cost only a fraction of the installation cost of the tile recuperator, and which presents from the standpoint of repairs a much easier operation than a tile recuperator, is sure to be the choice of both the engineer and the operator. To put the matter another way, if with a refractory recuperator a unit volume costs one dollar, and the installation costs, taking into consideration all of the items mentioned above, represent one dollar, it cannot compete with a metal recuperator with a unit cost of one dollar and an installation cost of twenty cents.

In the design of metal recuperators, Professor Trinks's paper has pointed out the factors of heat transfer which should be considered. One of these elements, which will go far to make the metal recuperator an unqualified success, is that factor of design which will enable the cold air to receive the heat from the recuperator metal at a much

greater rate than the hot gases give the heat up to the recuperator metal. If a condition can be approximated in metal recuperator design similar to that which obtains in a boiler tube, metal recuperators will not present a difficult problem to the designer or the operator. As soon as a metal recuperator can be obtained which will approximate the temperature of the air—in other words, as soon as the air can be used to keep the metal cool—then the possibilities of burning out the recuperators will be greatly reduced, particularly if the factors of combustion have been adequately considered.

V. P. Griffin:* I have reviewed the results of tests of a number of air preheaters installed in connection with steam-boilers and have found that the rise in air temperature is in every case greater by several degrees than the reduction in the temperature of the stack gas. This discrepancy results from the air leakage into the gases in the last passes of the boiler, and from auxiliary air being supplied to the furnaces through sources other than the preheater.

A. L. Culbertson:† Until recently a pressure from 2 to 10 inches of water was always used in all recuperators and it has been convincingly shown that this pressure was the cause of the failure of so many types of recuperator. It is likewise this pressure, an inherent weakness in the design of the recuperator, which has caused the thought of leakage to be uppermost in the minds of all who consider its installation. Such a pressure may be caused by restricted ports, small flues, or the many baffles and turns which might be in the recuperator itself.

A pressure of from 2 to 10 inches of water is more than a thousand times higher than the pressure for which the Chapman-Stein Furnace Company designs its recuperators and under which they operate successfully without leakage. The pressures in a Chapman-Stein installation vary from approximately minus 0.01 inch at the air-inlet valves to plus 0.01 inch at the furnace ports. It is evident that when working with this low pressure the calculations for ports, and the sizes of the ports, must be very exact in order that they may function properly. It is also easy to see that, where we work in thousandths of an inch, an error of 0.01 inch would be disastrous to operating

*Combustion Engineer, Duquesne Light Co., Pittsburgh.
†Vice-President, Chapman-Stein Furnace Co., Mt. Vernon, Ohio.

results. On the other hand, when a pressure of 10 inches is being used, an error of 0.01 inch (or even one inch) in port design would be scarcely noticed. High port velocities and corresponding pressures tend to cover up imperfectly designed ports, but at the same time result in the high pressure which must be carried through the recuperator, and is exceedingly disastrous to this apparatus by causing any small cracks to leak tremendous amounts of air to the stack flues. When the recuperator leaks, the operator will frequently by-pass it entirely, as Mr. Trinks has already stated this morning.

A few calculations will bear out the statement that pressures from 2 to 10 inches mean disaster to the recuperator. I have taken a typical continuous-furnace recuperator (in fact the figures are obtained from one in process of construction) and found that the number of tile used in this recuperator have a total of 114,840 inches of joints which could be considered possible cracks for the leakage of air to the waste gas. I am going to compare the results which would be obtained with regard to leakage when considering this recuperator under two different pressures—(1) that under two inches of water pressure; (2) that for which it is designed, following Chapman-Stein precepts. The comparison should show in a quite obvious manner the reason for the success of the Chapman-Stein recuperator and should also demonstrate the cause of failure of so many recuperators of old design.

Our calculations show that 78 cubic feet of air at 32 degrees are required through the recuperator every second. Considering the temperature of the air leaving the recuperator as being 1300 degrees F., let us assume in each case that the average temperature for the air throughout the recuperator is 650 degrees F. At the temperature of 650 degrees F., the 78 cubic feet have increased in volume to 175.5 cubic feet.

Let us go even further and instead of considering 2 or 10 inches of pressure let us consider between the air and the waste-gas flue a differential of two inches, which is sufficient differential to cause approximately a velocity of 100 feet a second. With this velocity it is obvious that an opening of 1¾ square feet will cause the loss of the entire air supply (175 cubic feet). An opening of 1¾ square feet could be formed by cracks ⅛ inch in width and 2016 inches in length, and might be caused by expansion, contraction, or any shifting which

might occur through the recuperator structure, and thus the cracks necessary to lose all of the air for combustion would need to be but 1.75 per cent. of the total available. This would be reduced to less than one per cent. if the higher pressure of 10 inches were considered.

Now consider the velocities and pressures actually found in the Chapman-Stein type of recuperator. The differential found is a very small amount, due to the fact that both the air flues and the waste-gas flues are under suction. The air flues are under suction due to their own stack effect, and the waste-gas flues are under suction due to the main stack pull. The differential between the waste gas and the air is theoretically zero, since we attempt to obtain a "balanced-draft" condition. The differential found due to actual operating conditions is exceedingly small. For purposes of comparison, however, let us consider the same amount of air as above (175.5 cubic feet per second at an average temperature of 650 degrees). The area of the air flues operating under their own stack effect in the Chapman-Stein recuperator is such that a velocity of only 3.9 feet a second is required to deliver this amount of air. Consider, therefore, the differential as that which would cause this velocity of 3.9 feet a second. Then $175.5 \div 3.9 = 45$ square feet of cracks which would be required to cause a total leakage of the air to the stack. This area of 45 square feet is the equivalent of a crack ⅛ inch wide and 51,850 inches long, and 51,840 is 45.2 per cent. of 114,840, which is the total possible area of cracks.

This comparison is quite obvious. In the case of two-inch pressure, 1.75 per cent. of the total cracks gives complete leakage. In our own case 45.2 per cent. cracks gives complete leakage. One or two per cent. of the cracks would be negligible in the Chapman-Stein recuperator, since it is designed in itself to provide 200 per cent. of the total amount of air required and would only be losing a very small portion which would not even be noticed. On the other hand, it would be disastrous to the pressure type of recuperator.

If pressure of from 1 to 10 inches is being used on your recuperator, watch out for cracks in the recuperator, as the slightest amount will greatly reduce the benefit of the recuperator, and the higher the pressure the less cracks are required to lose all the air required for combustion. This holds good not only with tile recuperators, but with metal recuperators as well, and the recuperator

which is designed to overcome leakage must of necessity work on low differential pressures, which again means great care and accuracy in port design.

R. E. Cramer:* I should like to ask Professor Trinks how the location of a preheater affects heating. For an example we may consider a billet-heating furnace of the continuous type, with end discharge. Before application of a preheater the waste gases are taken off the rear end of the furnace and into an underground flue, thus resulting in what might be called a "down draft" at this end of the furnace. Let us assume now that a preheater is installed on top of the furnace at the rear end and the gases taken upward, thus reversing the direction of the draft. I should like to have the speaker's opinion as to the effect of this change on the distribution of the gases in the furnace and the effect on heating as regards the top and bottom of the billets.

Willibald Trinks: It would have a very slight effect. The rear end, drawing heat downward between the billets, should have a slight effect on heating the billets at the cool end of the furnace. If you put a recuperator on the top, that is just as good as a hole in the roof. Now if the roof is very far above the billets it would draw the gases along the roof and would not allow them to come in contact with the billets as much as the down draft does; but you can draw a brick curtain across the rear end of the furnace and compel the gases to stay down. Several furnace engineers have adopted that scheme. Instead of keeping the arch as heretofore you make a low-lying flat arch at the rear end and thus deflect the gases downward. I know that this design was used years ago by the National Tube Company, at McKeesport. The curtain rested on a water-cooled pipe. With this method I think you will find very little difference in heating between having the recuperator at the top and having it at the bottom.

A. L. Culbertson: The same results could be obtained by withdrawing the waste gases at the bottom of the furnace to an underground flue; then out to each side of the furnace and up on the

*Assistant District Engineer, American Steel & Wire Co., Pittsburgh.

outside. It would be entirely wrong to have an outlet in the crown of the furnace leading to the overhead recuperator direct, unless something is provided to hold the gases down close to the steel.

WILLIBALD TRINKS: Referring to a curtain, I wish to say that the latter can be used only where the billets are reasonably straight. If you have sheared billets which lie crooked in the furnace, the curtain is no good, because the billets will soon rip the curtain out.

I think the questions that have been asked me have all been answered and I have nothing more to say except to ask Mr. McLoughlin how his Morgan recuperators are doing at Duquesne. I understood they were excellent when the mill rolled the same sections for a long time without change. The present method of changing from one section to another, due to buying from hand to mouth, may have changed the performance of the recuperator.

T. J. MCLOUGHLIN:* I think Mr. Trinks's surmise as to the conditions under which steel-mills operate at the present time is correct. In the old days I have known a mill to stay on the same size for three or four weeks, but that condition does not exist at present. The Morgan furnaces at Duquesne are still giving excellent service, although their efficiencies are lowered slightly due to the condition of operation. There is a question I should like to ask about applying air preheaters to boilers. Often a boiler-plant operator is called upon to generate steam with a great variety of coals, having an ash with a fusing-point varying from 1850 to 2600 degrees. With such fuels, the preheat possible on underfeed stokers must be varied to suit the fusing-point of the ash. What is the most economical method to use? Is it better to by-pass the products of combustion, or the air, or both?

WILLIBALD TRINKS: I think Mr. Dyrssen can answer that better than I can.

W. DYRSSEN:† The variation in temperature of air, due to the reversals in the Blaw-Knox heater, is very small and tests that we have made on a heater (using waste gases of a temperature of about 1000 degrees) show that it takes a very sensitive thermo-couple made

*Fuel Engineer, Carnegie Steel Co., Duquesne, Pa.
†Chief Engineer, Furnace Equipment Department, Blaw-Knox Co., Blawnox, Pa.

up of very fine wire to show any temperature variation at all. Ordinary thermo-couples do not show any variation. We also experimented with varying the time of reversal from one minute to three minutes, but we could not find that the longer reversal was not just as good as the short time of reversal. We are now reversing our heaters in three minutes, which means that the heating elements are exposed to waste gases for about 1½ minutes and to air for about 1½ minutes. From an operating point of view it is, of course, better to reverse as few times as possible. The actual motion of the valves takes place during about 30 seconds, so there is no shock of any kind in connection with the operation of the valves. There is no variation in the flow of air and waste gases through our heater.

WILLIBALD TRINKS: Is that the variation in temperature? That is what I want to know.

W. DYRSSEN: I have just explained that it takes a very sensitive thermo-couple to show any variation in air temperature and that this variation is only a few degrees in any case.

A. L. CULBERTSON: How far would it be necessary to go from the regenerator until very little change would be noticed?

W. DYRSSEN: The temperatures were taken in the flues from the air heater.

A. L. CULBERTSON: I thought possibly the brickwork in the flues themselves would tend to equalize the temperature and would eliminate any changes which might occur due to the regenerator itself.

W. DYRSSEN: The temperature of the walls in the flue may tend to make a more uniform reading of the thermo-couple, but even with a very sensitive couple the variation in air temperature is only a few degrees.

B. S. SPRAGUE:* It would be possible to calculate from the known weight and specific heat of the plate material in the preheater

*Electrical Engineer, West Penn Power Co., Pittsburgh.

and of the air passing through the preheater, the variation in temperature of the plates and of the air leaving the preheater. Can you give us any idea of the amount of this temperature variation?

W. DYRSSEN: In testing our air heater we had the thermocouples welded to the plates and we actually got the variation in the temperature of the plates, which checked very nicely with the temperature variation that could be expected from calculations. With the three-chamber arrangement of our heater there is one chamber coming in on air while one chamber is going off, and this tends to equalize the temperature of the air considerably. The heating plates are 1/16 of an inch thick, and the temperatures of the plates do not vary more than 20 to 50 degrees, depending on the temperature of air and waste gases, and this temperature variation is not sufficient to make any appreciable variation in the temperature of the air leaving the heater.

A. L. CULBERTSON: If it takes 30 seconds for the valve to close, where does the air go in the meantime? Is it short-circuited to the stack or lost to the atmosphere?

W. DYRSSEN: I think that the diagram shown in Fig. 17 will show you exactly what happens in the reversals. With a time of three minutes for one complete reversal, the valves in one chamber will close slowly during 30 seconds, while the valves in another chamber are slowly opened, so that the air is slowly transferred from one chamber to the other, and this makes the flow for both air and waste gases through the heater absolutely continuous. The air-valves and the gas-valves in the same chamber are never open at the same time, so that no mixture of the air and waste gases can take place, and continuous flow is obtained by the three-chamber arrangement, with slow movement of all valves in a certain sequence.

H. C. MCCUTCHEON:* In a furnace on which a recuperator is to be installed, how much will the design of the checker chambers affect the benefit to be derived from the recuperator?

*Open-Hearth Superintendent, American Rolling Mill Co., Ashland, Ky.

W. H. Fitch:* The best information we have obtained on the question of heating surface of regenerators and the volume for the most economical results is 100 cubic feet of checkers per ton of metal poured. It seems that the average furnace of to-day has checker volume of about two-thirds or less of the above amount, leaving the final reduction of temperature of gases after the regenerators to be accomplished by the waste-heat boiler. What we propose is an application

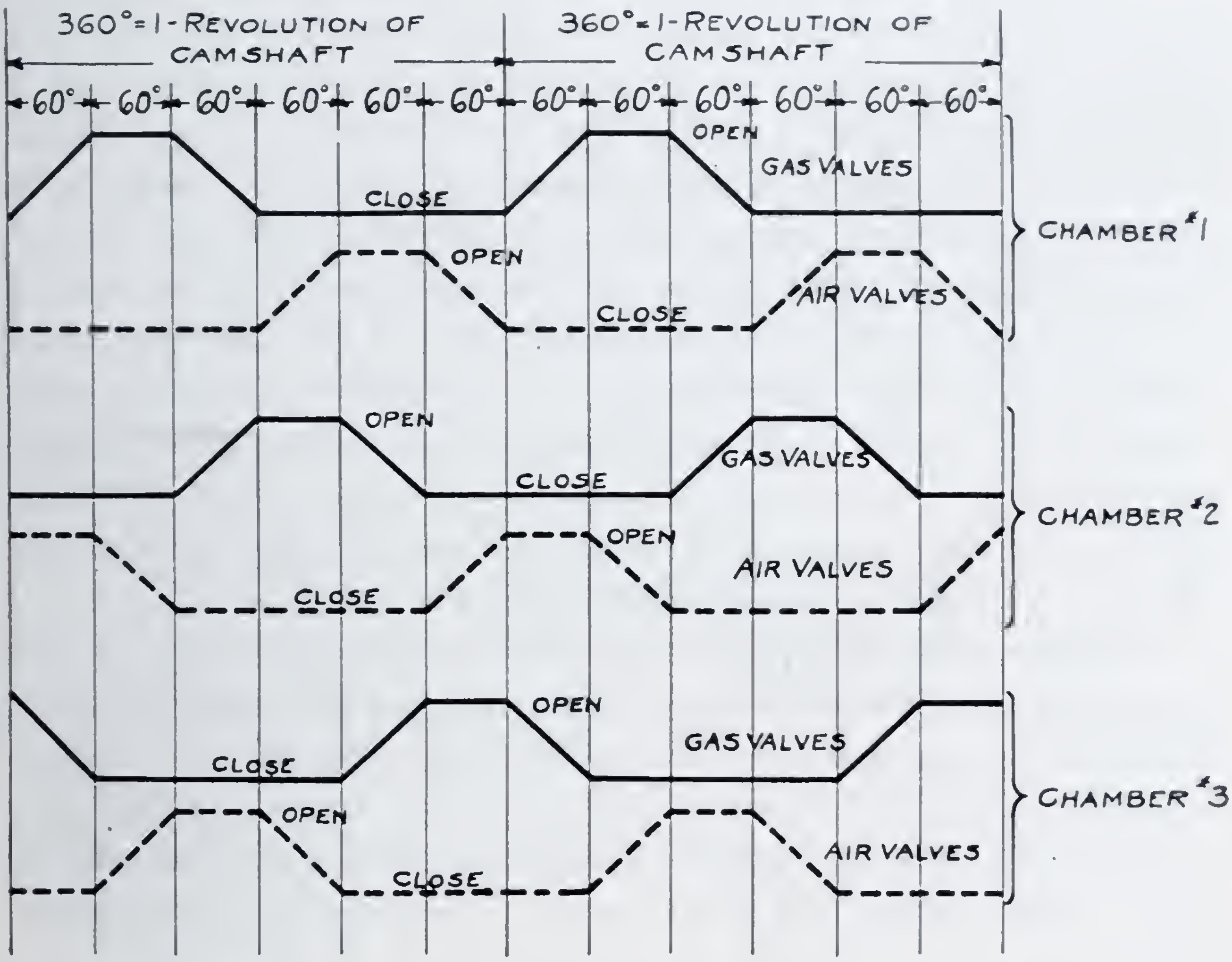

Fig. 17. Movement of Valves in Blaw-Knox Regenerative Air Heater.

of a recuperator instead of a waste-heat boiler. By returning 20 per cent. of the heat that would escape up the stack where a waste-heat boiler or recuperator is not used, useful work would be done at a comparatively low initial cost.

Willibald Trinks: I wish to point out that, although this is primarily a district of cheap fuel, half of the recuperator builders in the United States are located in Pittsburgh. I would like to ask Mr.

*Consulting Engineer, Allentown, Pa.

Fitch this question. If we make the regenerators as they are now and make use of the flues between them and the reversing-valve, could we not increase the heating surface of the regenerator, without going to the recuperator scheme, by using additional regenerator brick of carborundum?

W. H. Fitch: In operating a 20-ton air furnace, over a period of three years, for making malleable castings for subsequent annealing, we secured some interesting data as regards dust accumulation. The furnace in question was equipped with a waste-heat boiler, and built with a slag chamber. Pulverized coal was used as a fuel. After leaving the slag chamber, going towards the boiler, say a distance of three or four feet, there was no accumulation of ash of a molten nature. That ash which was carried into the combustion chamber of the boiler was in the form of a fine, dry powder that was easily removed with a steam-jet. This fact was used in the study of recuperator application to the open-hearth furnace. Considerably more non-combustible matter is carried over in this instance than would be found in the operation of an open-hearth furnace of the same capacity using any fuel other than pulverized coal.

Where an application of this kind is considered, there are a great many questions that can not be answered accurately until an application has been made; however, it seems reasonable to suppose that practical results can be obtained with the furnace-gas temperatures entering the first pass of tubes, as they are well below that at which molten matter would be carried in suspension in our proposition.

A. L. Culbertson: I would like to say a few words concerning an open-hearth furnace in conjunction with a recuperator. In the first place, a recuperator is considered mainly a heat-transfer apparatus, although, of course, there is a small amount of storage. A regenerator is commonly considered a heat-storage apparatus, since it stores up heat during the passage of the waste gas and gives it up on the next reversal. The recuperator, however, is constantly transferring the heat from the waste gas to the air and does not rely on its mass for storage purposes. I consider that recuperators are desirable and advantageous on many types of furnaces, but they are not a

cure-all. In some cases a regenerator is the proper apparatus to install. I believe that the open-hearth furnace is one type of furnace for which regenerators are best suited. Considering an open-hearth furnace working with all cold charge, or a large proportion of cold charge, the outgoing gases for some time would be at an appreciably low temperature due to the enormous heat absorption of the cold charge. Since the recuperator transfers the heat, it appears that it would be giving up a very small amount of heat to the air just at the time when highest temperatures are most desirable for quick melting. This, of course, is due to the fact that recuperators have a very much smaller heat storage than the regenerators. Now take the case of the regenerator. Due to the mass of checkerwork, and also considering the side walls and flue bricks, uptakes, etc., for heat storage, a large amount of heat is stored up and is given up to the ingoing air in spite of the waste-gas temperatures having dropped off. It is my opinion that a recuperator applied to an open-hearth furnace would result in increased time of heats, and for that reason would not be very desirable.

H. C. McCutcheon: It will perhaps be better to ask the question without including recuperators at all. Mr. Fitch stated that all furnaces operating to-day have a certain fixed volume of checkerwork. It is evident that this volume can be obtained by a long, shallow chamber or by a deep one not so long. Will anyone here say whether checkers should be shallow or deep, and what effect will a variation in depth have on the way a furnace will work?

W. H. Fitch: For various reasons it is necessary to build checker chambers vertically instead of horizontally. Vertical chambers have produced the best results with a minimum of checkers. With the horizontal section being the greater, the result is that the hot gases going to the stack pass down through that section of the checkers nearest the stack and, when the reversal is made, the air rises through that section of checkers farthest from the stack, which helps to explain the inefficiency of the regenerator as a whole. If a regenerator could be designed to operate economically it would probably be impractical to install it due to the large amount of space required; therefore, a recuperator, placed between the regenerators,

with a heat-exchanging material capable of a high rate of heat transfer is suggested to give the desired results.

WILLIBALD TRINKS: This question of required depth of regenerator is very interesting. A regenerator is not only a heat-exchanging apparatus and a storage for heat; it also is an air-moving apparatus. The regenerator moves air into the furnace because the air is hot. We must have the regenerator deep enough and large enough to project the air all the way across the furnace over to the outgoing end without depending upon the stack. That means that if you have a very small furnace you can get along with a shallow regenerator. We must not forget that in most open-hearth furnaces the output is the important item. What the superintendent wants is all the steel that can be made in the furnaces with the fewest repairs. As far as the fuel engineer is concerned this may be the wrong standpoint, but the superintendent decrees that if we have to waste fuel, we are very sorry, but we must do it. Up to a certain point we can get more efficiency by making the checkers deeper and higher.

You have to consider the maximum output of the furnace. Area of ports; cross-section, area, and depth of checkers; and resistance caused by the flues, must all be considered. Moreover, the designer of regenerators works under restrictions. He is given a furnace with a definite amount of space into which to put the regenerator. I am for fuel economy every time, but there are conditions of space and of economics which no fuel engineer can disregard.

H. C. MCCUTCHEON: From what Professor Trinks has said, the depth of checker chambers will probably affect the way a furnace will run rather than the fuel consumption, and the port area should vary with the depth of the checkers.

A. L. CULBERTSON: I understand that the figure of 26 per cent. of air infiltration was given some time ago. It is evident that if there is 26 per cent. of air infiltration, the furnace must be operated under a minus pressure, or suction. This infiltration causes a loss of heat and a corresponding increase in the fuel required. If the pressure in the ports, which is determined by the depth of the regenerator, is sufficient, then the flame would be carried throughout the length

of the hearth without requiring the furnace to be operated under a suction sufficient to cause 26 per cent. infiltration of air. It is in this manner that I would connect the depth of the regenerator with the fuel consumption of this furnace.

T. J. McLoughlin: The excess air entering the regenerator of an open-hearth furnace comes in through the port end of the furnace. This amounts to about 25 per cent. by weight of the gases leaving the exit port.

RECUPERATORS
APPLIED TO OPEN-HEARTH FURNACES*

By W. H. Fitch†

The possibility of using recuperators for open-hearth furnaces has been a subject of discussion among operating men and engineers for several years. Those I have interviewed are divided into two classes—those who have waste-heat boilers or prefer this means of utilizing waste heat; and those who have no waste-heat boilers and prefer to return all of the waste heat to the furnace, if possible, making it a closed cycle.

In the case of one large company, the claim is made that the use of electricity for driving mills and machinery is gradually reducing the usefulness of waste-heat boilers, making the regenerator or the recuperator the only alternative. As the recuperator principle is looked upon with favor in many instances, a general discussion of the subject at this time seems justified on account of the benefits that may accrue from an engineering standpoint.

I have not applied the recuperator design in question to an open-hearth furnace. I have, however, made an installation in which the temperatures are quite similar to the open-hearth requirements.

The quantity of heat lost up the stack of an open-hearth furnace, operating under average good conditions, without a waste-heat boiler, is considerable. The average temperature of these gases in furnaces of a representative plant is approximately 1400 degrees F. In the case of a 100-ton furnace making a heat every 10 hours, and gasifying 600 pounds of coal per ton of steel tapped, the possible avoidable loss of fuel per annum (300 working days) up the stack is 4320 tons of coal. A reduction of temperature of gases from 1400 to 500 degrees F. when entering the stack would be equivalent to a saving of 20 per cent. of the fuel fired. At $5.50 per ton of coal gasified ($4 for coal delivered and $1.50 for gasification), the savings would be $23,760 a year.

In present practice, the temperature of air going to the furnace varies greatly. This must cause a loss of time in making a heat. If this temperature difference can be modified and an hour can be de-

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†Consulting Engineer, Allentown, Pa.

ducted from the time of making a heat, the result will be an increase in production. This value, added to 20 per cent. saving of fuel, would make a substantial total saving.

Practically all furnaces in service were built with gas and air regenerators at each end of the furnace. The checker volume of each probably averages only 35 cubic feet per ton of metal tapped. In a number of plants, where furnaces were built with checker volume of good proportion, the hearth has since been enlarged. As the checker volume could not be increased, the ratio of checker volume to ton of steel tapped has been reduced to such a point that it is not economical. In some small plants furnaces have as low as 20 cubic feet of checker space per ton of steel tapped. In these cases the stack temperature is obviously comparatively high.

To change the construction of existing furnaces for increasing the economy would obviously be impracticable. To build a new furnace with the present type of regenerator, and of sufficient capacity to return all of the desired waste heat to the furnace, would undoubtedly be so expensive as to be prohibitive.

The low efficiency of regenerators in service at the present time is recognized and understood by engineers.

The use of fuels of high calorific intensity has changed operating conditions so far as furnace design is concerned. Furnaces fired with coke-oven gas, tar, and fuel-oil do not require preheating of the gas. The preheating of air only is economically necessary. Indeed, a number of operators have expressed the opinion that it is not necessary to preheat producer gas where it can be delivered to the furnace ports at 1200 degrees F.

With the adoption of fuels which do not require preheating both gas and air, checkers may be used for air only, thus substantially increasing the heating surface and temperature of air. Even under this condition, the total heating surface would not, in many cases, be sufficient to give the desired economical results. This last condition is the particular problem in which I am interested and for which the following comments are intended.

The use of a recuperator, in combination with regenerators, is illustrated by Fig. 1-3. The recuperator is added to the present furnace without any change other than flue connections for reversing-valves. In all furnaces which I have studied there is sufficient space

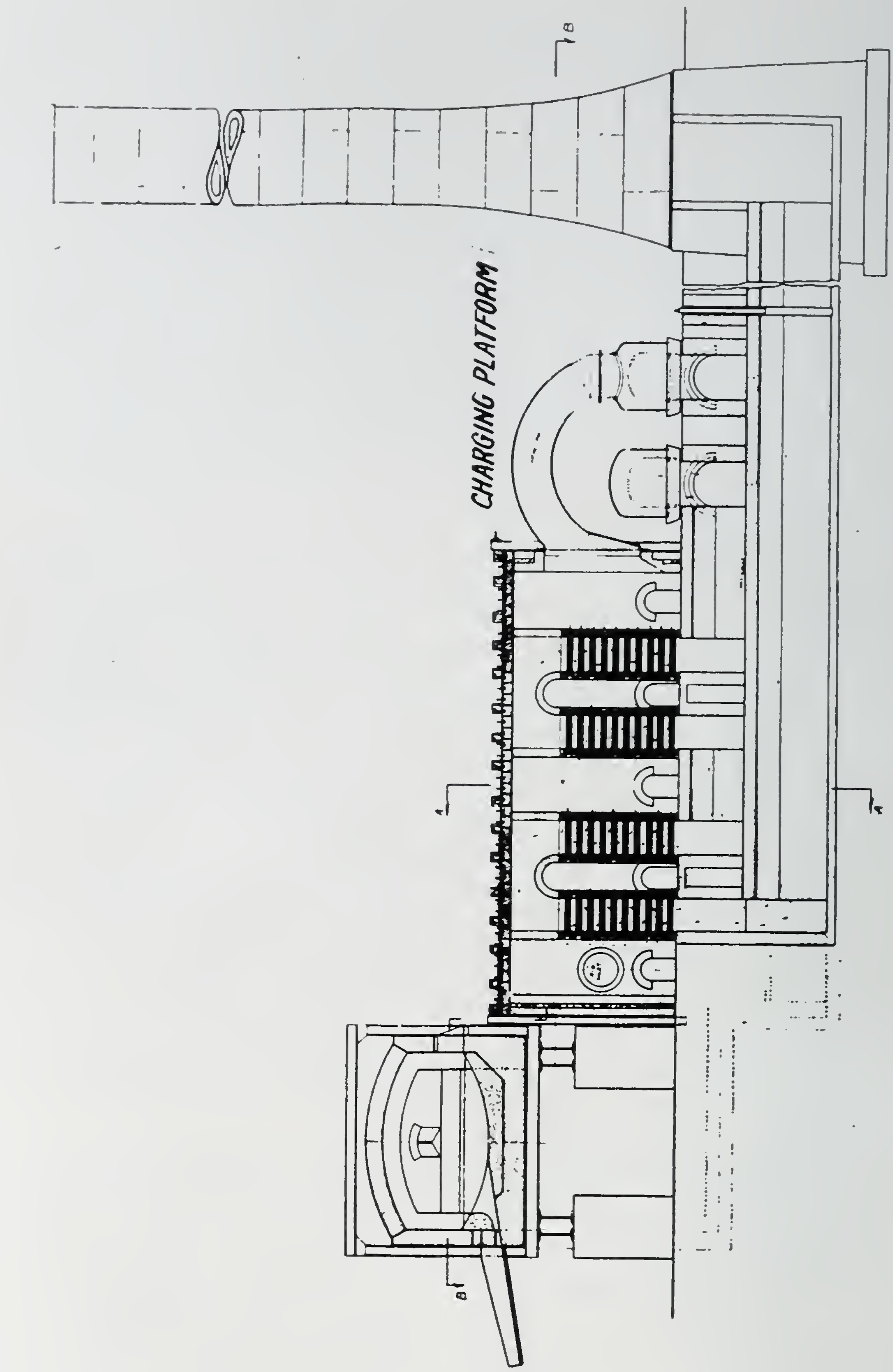

Fig. 1. Recuperator Combined with Regenerators.

between regenerators for a recuperator of the required size. With the checker and recuperator combination, the temperature of the air entering the checkers from the recuperator would be practically constant at 1000 degrees F. At reversal, the checker temperature on the end in question would be maximum. This would decrease in propor-

tion to the decrease in temperature of the air going to the furnace, and until the economical heat transfer limit was reached at the time of the next reversal. With air at 1000 degrees F. entering the checkers, the variation in the temperature of the checkers, and consequently of the air passing through, would be much less than that of air entering checkers direct from the atmosphere. Advantageous results in the temperature of the furnace are apparent.

The use of a screen or checker chamber before the recuperator is desirable for the purpose of removing the oxids and dust, thus clean-

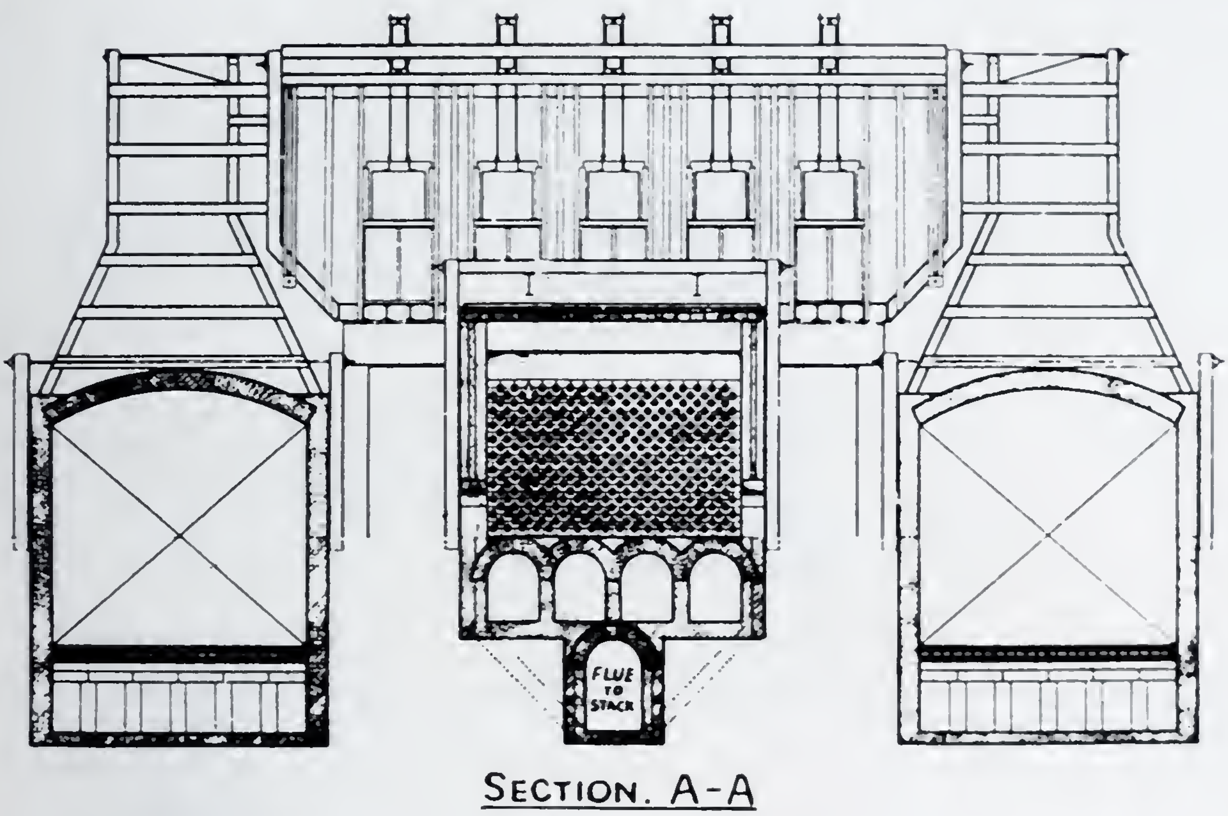

Fig. 2. Recuperator Combined with Regenerators.

ing the gases before they reach the first pass of tubes. The tubes will not deteriorate at any temperature found in practice of this kind.

The volume of checkers required per ton of steel tapped, to clean the gases satisfactorily before they enter the first pass of tubes, may be easily determined. The smaller the space requirements of the entire regenerator combination, the more attractive its use will be from a physical standpoint.

Although several shapes may be used, the tubular form is very efficient for the flow of gases. The tubes, made of silicon carbid, are glazed, protecting them from oxidation. This permits the maximum rate of heat transfer per square foot of heating surface per degree per

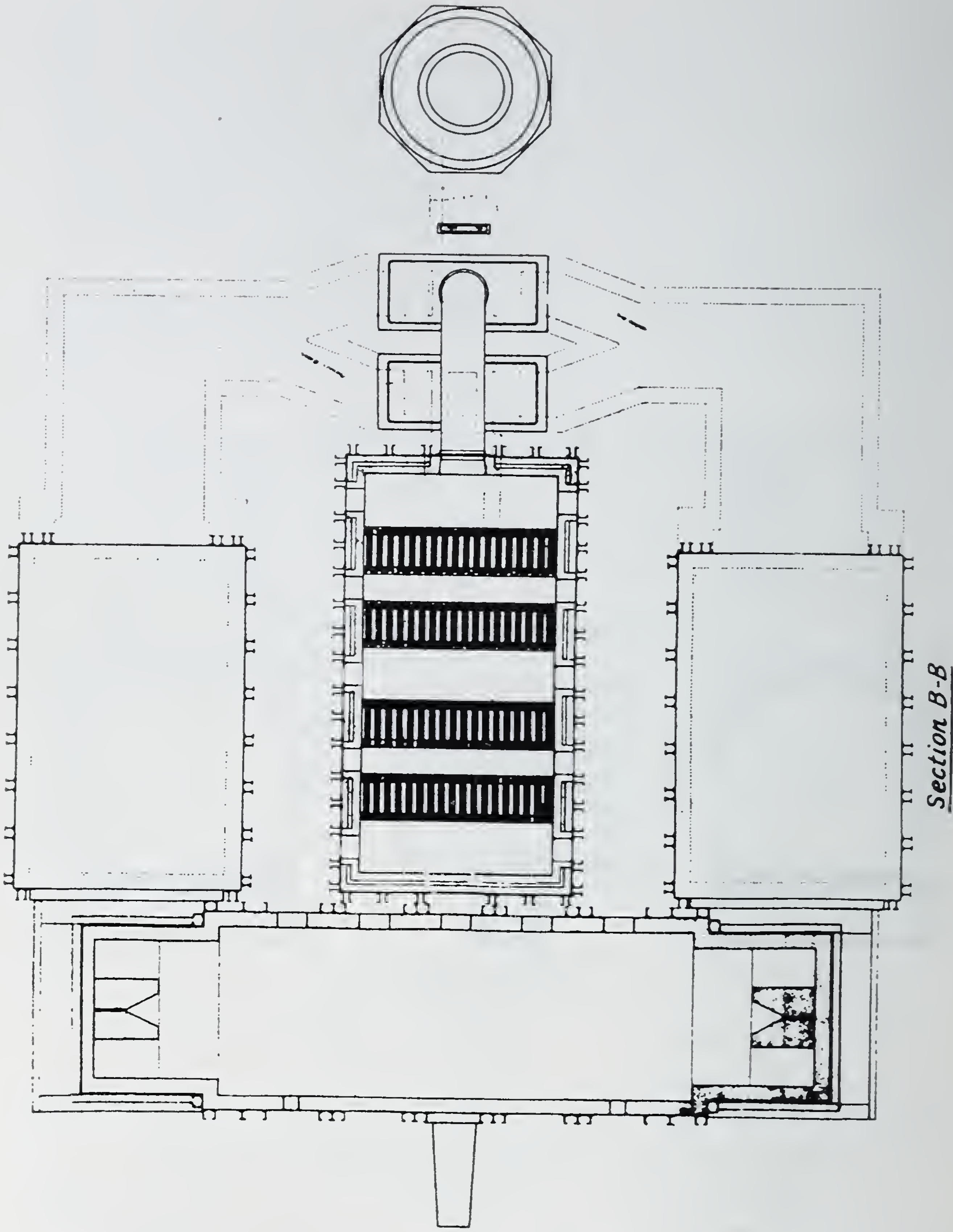

Fig. 3. Recuperator Combined with Regenerators.

hour. The tubes are made in one piece. There are no joints in the tube surface exposed to the direct action of the furnace gases, hence the possibility of leakage is reduced to the minimum. The tube ends are effectively sealed by cementing. The tubes are installed after the tube terminal walls are erected. The tube terminal walls are special shapes, made of fire-clay, and designed to facilitate the removal of tubes. This construction affords between the tube sections a chamber

or compartment large enough to admit a man for inspection and removal of a tube.

"Corebusters," as shown in Fig. 4, are employed to compel the air to pass in contact with the wall of the tube. The "corebusters" consist of solid cylinders made of fire-clay. Legs are fitted for center-

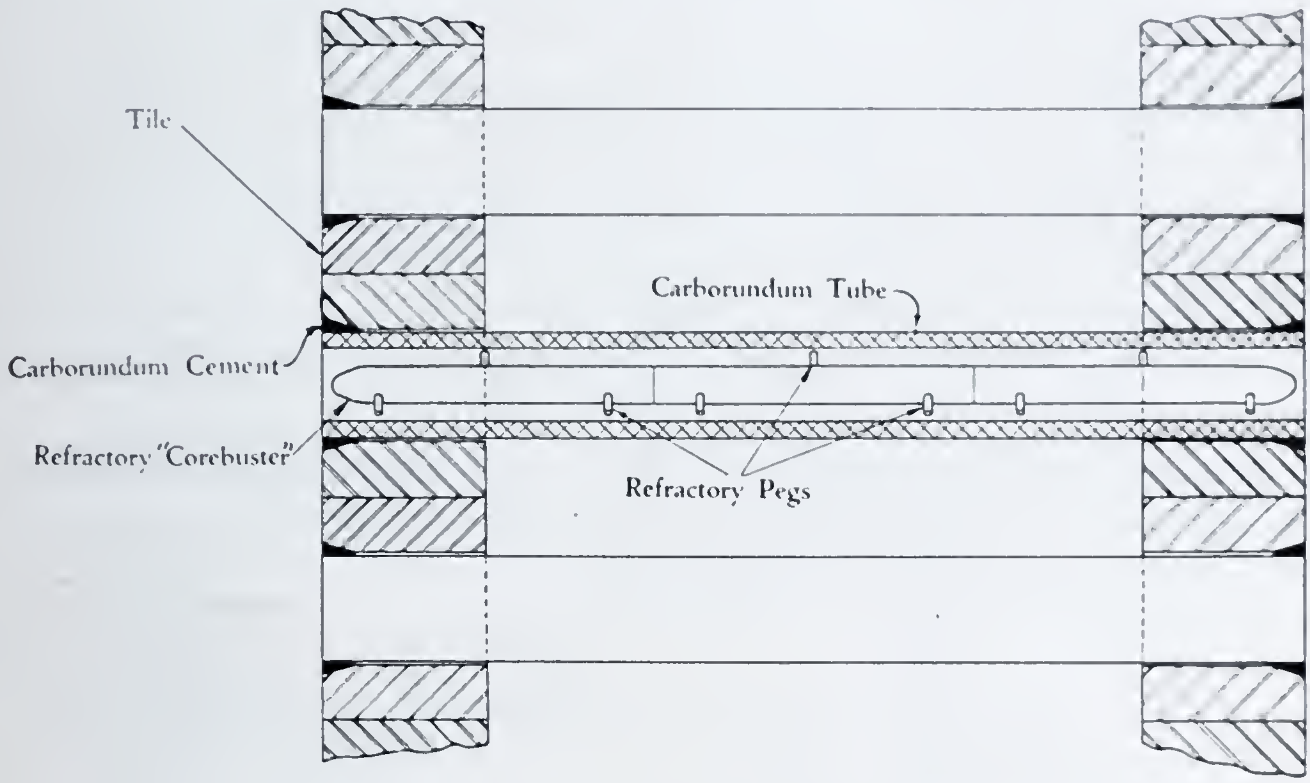

Fig. 4. "Corebuster."

ing them in the tubes. "Corebusters" are used in all of the tubes. They are made in three sections, each 17 inches long. The center section is made of uniform diameter, while the end pieces are pointed to facilitate the flow of air into and out of the tubes.

The heating surface of the recuperator, illustrated in the open-hearth furnace, is approximately 7500 square feet, or 111 square feet per 1,000,000 B.t.u. fired per hour. This requirement is based on the gas from 500 pounds of 13,500 B.t.u. coal entering the furnace per ton of steel poured, with temperature of furnace gases entering the recuperator at 1400 degrees F. and reduced to 500 degrees F. at the stack. A loss of heat equal to 100 pounds of coal is estimated for gasification of coal. This recuperator capacity is based on what is being done with recuperators now in service.

The amount of heating surface in the total unit (regenerators and recuperator) is estimated to be equivalent to the cubical capacity of a regenerator of standard cross-sectional area and 122 feet in

length. The difference in capacity of the present standard regenerator and the proposed combination is explained by the difference in the kind and thickness of the materials used in design of the recuperator.

Standard valves are shown. This illustrates the simplicity of applying a recuperator to an existing furnace.

In the installation shown in Fig. 5, the furnace gases enter the recuperator at point A, and pass in one direction—around the tubes—to the stack E. The furnace gases pass the tubes in a vertical column, thus utilizing all of the heating surface of the tubular members. The air for combustion passes through the tubes entering at B, intermingling at C and leaving at D. The combustion air flows continuously in one direction through tubes. After passing through the tubes the air is reversed from one end of the furnace to the other alternately as required.

How the construction of the recuperator influences the results as to uniformity of temperature of combustion air leaving the recuperator is evidenced by the following data:

	Temperature degrees F.		Draft, inches of water
Preheated air			Plus
Entering first pass	45		0.61
Entering second pass	340	top	0.47
Entering second pass	275	bottom	0.46
Entering third pass	540	top	0.38
Entering third pass	530	bottom	0.36
Entering fourth pass	755	top	0.28
Entering fourth pass	720	bottom	0.26
Leaving fourth pass	890	top	0.16
Leaving fourth pass	890	bottom	0.13
Flue-gas			Minus
Entering first pass	1290		0.26
Entering second pass	1185		0.29
Entering third pass	1000		0.45
Entering fourth pass	880		0.51
Leaving fourth pass	610		0.73

Two of these recuperators were installed in a double-chamber, car-type kiln for the manufacture of face brick at the plant of the Hanley Company, at Summerville, Pa., about a year ago. Each half of the kiln has its recuperator, which is located about 150 feet from

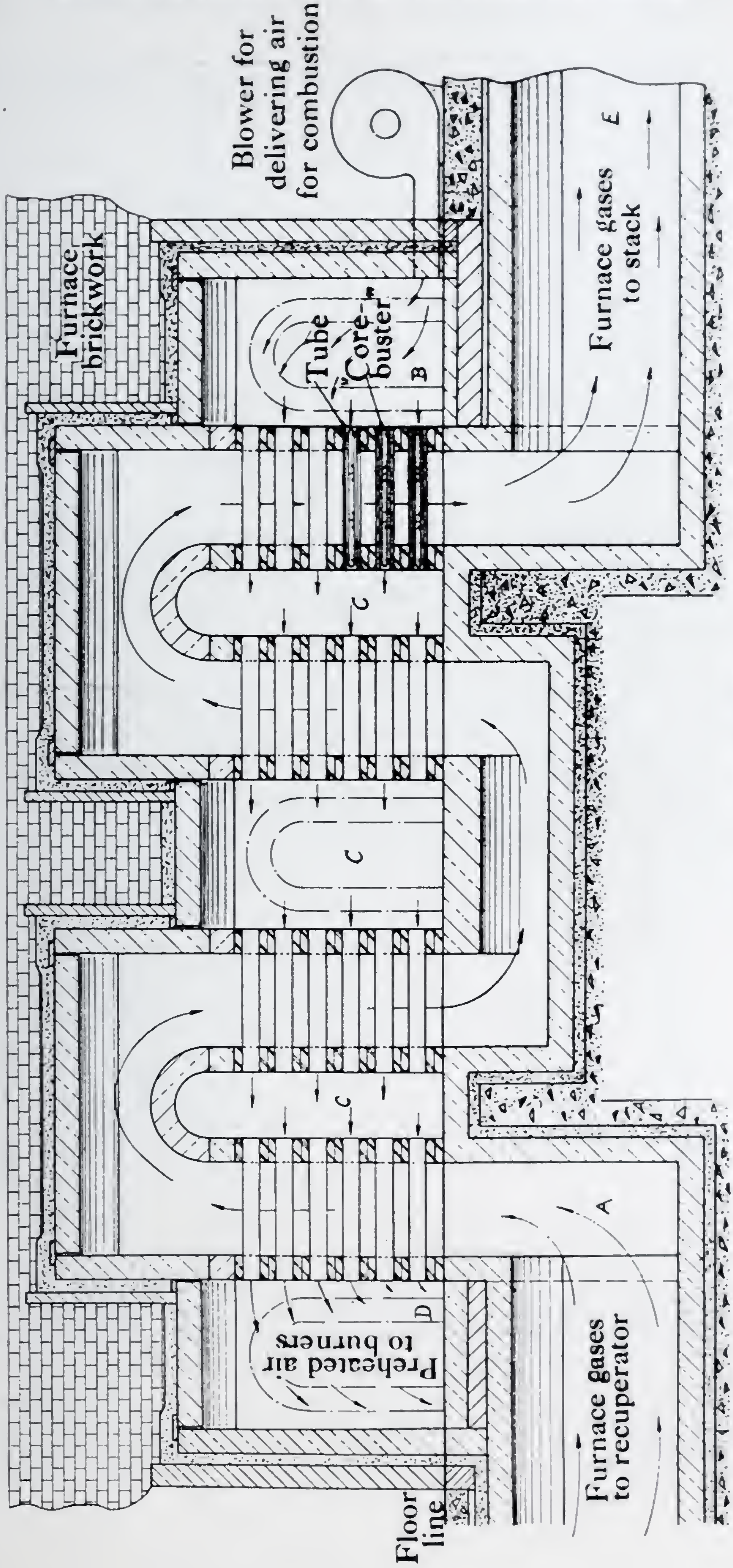

Fig. 5. Flow of Gases.

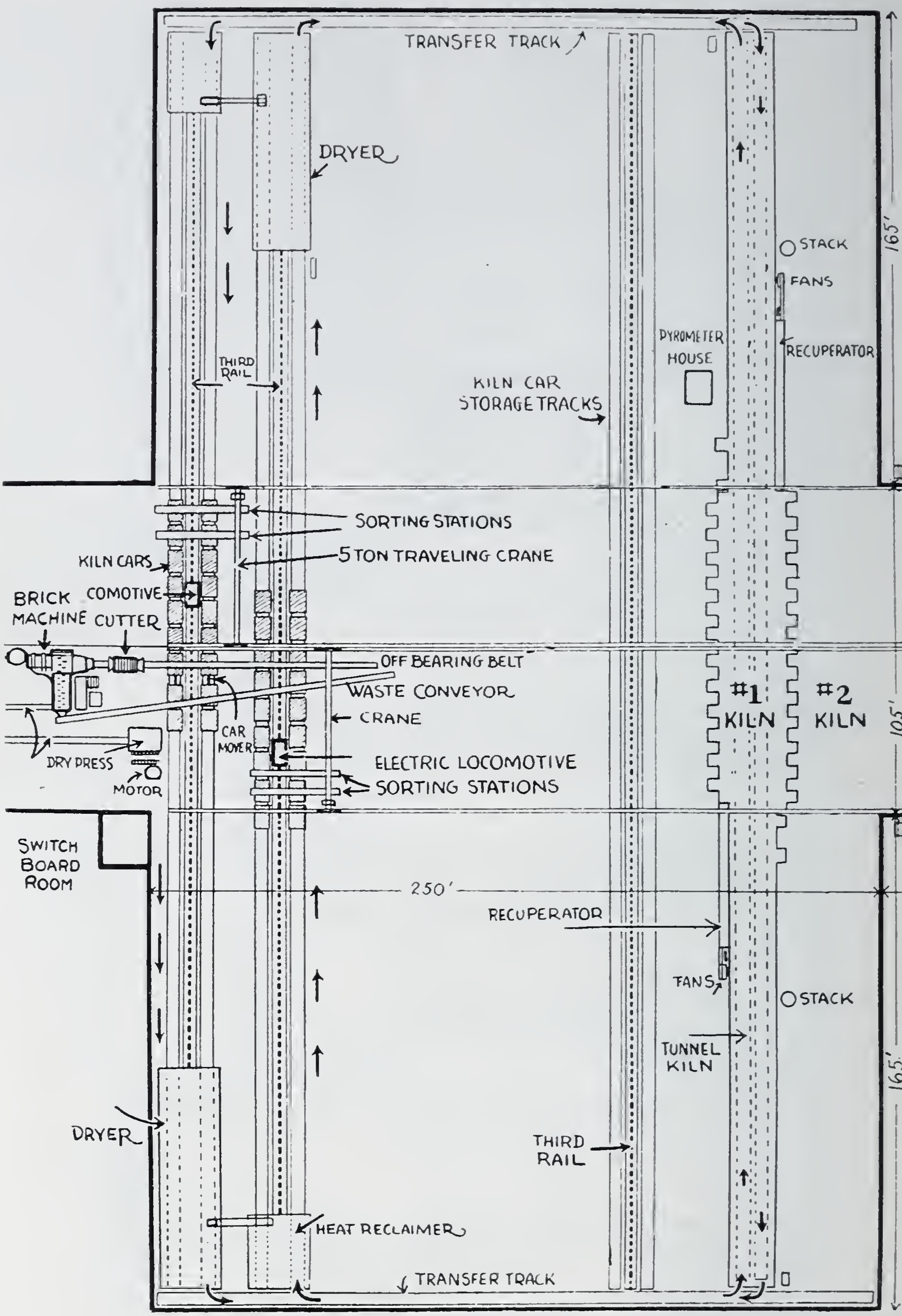

Fig. 6. Arrangement of Kiln and Recuperator.

the discharge end. The recuperators were designed for natural-gas fuel and to deliver the waste gases to a drier at about 500 degrees F.

Fig. 6 is representative of the general arrangement of one-half the kiln and its recuperator. The illustration is from an article in *Brick and Clay Record,* August 31, 1926, page 338.

It is interesting to note that the results of operating these recuperators compare favorably with the results obtained with metallic recuperators, though the use of refractory materials was not expected to yield results that would compete with the use of metallic substances in work of this kind and under similar conditions. As a matter of fact, the recuperators at the Hanley plant were designed for furnace gases entering the first pass of the recuperator at 2000 degrees F., whereas this temperature has not exceeded approximately 1400 degrees F.

An interesting and important factor in the operation of these recuperators is that practically no leakage has been discovered between the passageways for furnace gases and combustion air. This is undoubtedly due to the facts that the coefficient of expansion of silicon carbid is only slightly below that of fire-brick, and that the change in volume with change in temperature in this practice is almost negligible. Valuable data on the uses of silicon carbid will be found in a paper on "Thermal Conductivity of Carborundum Refractories," by M. L. Hartman and O. B. Westmont, in the *Journal of the American Ceramic Society,* May 1925.* A study of the design of walls and roof housing the tubes is worth while. All gases are mechanically controlled.

There is not much difference of opinion among operators as to the advisability of using gases under pressure in the operation of a recuperator if the design will permit. Production is the all-important item. To have a furnace which can be put in operation quickly, and is not dependent upon stack draft, is an advantage that is looked upon with favor.

In applying a recuperator to an open-hearth furnace it is expected that higher waste-gas temperatures than 1400 degrees F. will be met with eventually after the true value of the recuperator is known. In the case of higher temperatures, the rate of heat transfer will be much greater than found at 1400 degrees F. This is an advantage, however, in that more work can be done per square foot of heating surface. The probable maximum temperature is not con-

*V. 8, p. 259.

sidered a problem, inasmuch as the decomposition point of silicon carbid is above 4000 degrees F. There are no physical transformations at any temperature below decomposition, or certainly not at any temperature that may be found in practice of this kind.

In the event of a tube becoming damaged, the leakage of air would be a small percentage of the total and this air would mingle with the stack gases. In all probability it would not be perceptible, and the leak would remain undiscovered until an inspection period. Since in present practice it is necessary to repair furnace walls and roof, as well as to clean checkers periodically, ample time would be provided for inspection of tubes, and the life of the recuperator could be prolonged indefinitely.

In applying the principle of my design of recuperator to an open-hearth furnace for the manufacture of steel, the only limitation appears to be the quantity, temperature, and nature of the dust that may be deposited on the tubes. With waste gases entering the recuperator at 1400 degrees F., the temperature of the walls of the lower tubes will not exceed 1150 degrees F. in the first pass and an average of several hundred degrees for the recuperator. This is well below the temperature of the plastic state of dust, and consequently the dust may be removed by the use of soot blowers, as is the case in boiler practice. This method has proved effective where pulverized coal is used as fuel in boiler plants of modern design, using coal of comparatively high ash content. In this practice 600 pounds of ash per hour projected into the fire-box is quite common. If 20 per cent. of this ash is precipitated on the tubes and settings, 120 pounds would be removed periodically.

An open-hearth furnace fired with coke-oven gas is not exactly comparable to a boiler fired with an equal value of fuel in the form of pulverized coal, per unit of time, due to the difference in the nature of the non-combustible substances found in the flue-gases. However, if the quantity only is to be considered, the dust in the case of the boiler is many times that to be found in the open-hearth furnace, and may be compared.

Referring to a paper by F. W. Schroeder and B. M. Larsen entitled "Progress Report on the Effect of the Open-Hearth Process on Refractories," * we find that the precipitation from the gases entering

*Advance paper A. I. M. and M. E., July 1926. (Pamphlet 1579 C.)

the stack of an open-hearth furnace is 0.05 to 0.259 gram per 100 cubic feet, and that by far the largest percentage of this dust is composed of iron oxid varying from 50 to 95 per cent. in different samples. These particles have a severe corrosive action on silica and fire-clay refractories. The minimum temperature range for this corrosion with fire-clay and silica is around 2500 to 2600 degrees F.

The temperature of the furnace gases in the first pass of tubes would be about 1400 degrees F., or 1100 to 1200 degrees F. below the minimum corrosion temperature referred to above; so one is justified in concluding that serious reaction would not result on account of the use of silicon carbid in the manufacture of tubes.

On a basis of 0.259 grams deposited per 100 cubic feet of gases and 6000 pounds of coal gasified per hour, with all of the gases of combustion passing out of the stack at 1400 degrees F., as in present practice, there would be 1.41 pounds of dust deposited per hour on the recuperator tubes if it all stopped there. Undoubtedly, a smaller percentage is actually deposited, and this is removed at blowing intervals. This amount is almost negligible, compared with results of boiler practice using pulverized coal as a fuel.

DISCUSSION

D. B. Hendryx:* I did not come to this meeting prepared to discuss Mr. Fitch's paper, as I have never seen this paper, and am not familiar with the problem of applying recuperators to steel heating or melting furnaces. Possibly I can, however, give you some idea of the results which we have obtained during the past year from two recuperators applied to a continuous tunnel kiln for burning brick.

At our plant the green brick are loaded upon small cars holding about four tons each, and are shoved through a kiln 400 feet long, at a very low rate of speed. The central section of the kiln is fired with natural gas to a temperature of about 2150 degrees F., and the products of combustion are drawn off at 1500 degrees and put through the recuperators, which are of the high-velocity tube and "corebuster" type. The hot air is used principally for the cumbustion of the gas in the kiln.

The whole application differs from open-hearth furnace practice in almost every particular. The temperature of the products of com-

*Hanley Co., Bradford, Pa.

bustion is low, running from 1300 to 1600 degrees F., according to the capacity and temperature at which the kiln is being operated. Steel is usually heated in a neutral or slightly reducing atmosphere, to prevent oxidation; whereas, the vitrifying of clay ware is largely an oxidizing process, and is usually carried on with from 50 to 250 per cent. excess air. Open-hearth furnaces operate in cycles, with both quantity and temperature of exhaust gases changing, while our kiln operates steadily at an even temperature and with uniform fuel consumption. The exhaust gases from steel furnaces are often laden with dust and molten slag, while the products of combustion from natural gas in a brick-kiln are about as clean as can be found on any furnace.

It may be interesting to note that only about 28 per cent. of the total heat supplied to the furnace section by the burning gas and preheated air is retained by the brick in this part of the kiln, while 38 per cent. is removed from the gases as they pass through the recuperator. Of the remaining 34 per cent., about half is used in the driers, and the remainder escapes to the stack. While the recuperators show a very high percentage of saving in this installation and indicate a return of nearly 50 per cent. on the money invested in them, it should be remembered that they were not applied to an existing kiln with an idea of increasing its efficiency, but rather that the kiln was designed to be used in connection with recuperators, and would not be very successful without them.

The first question always asked when discussing recuperators is, "What preheated air temperature do you get for a certain gas temperature entering the recuperator?" I particularly want to call your attention to the fact that the temperature to which the air is heated has no direct relation to the efficiency of the recuperator except when we know what proportion of the hot gases from the furnace is exhausted through the recuperator, and how much air is passed through to take up the heat from the cooling gases. This is well illustrated in our own experience.

At one time the products of combustion from the kiln entered the recuperator at 1290 degrees and left at 610 degrees F., with a drop in temperature of 680 degrees, while the air was raised from room temperature to 890 degrees. It is very evident that all of the air for combustion was not put through the recuperator, but that a portion of it was admitted as cold air at the burners. Just at present, the flue-

gas enters at 1480 degrees and leaves at 710 degrees, a drop of 770 degrees, while the temperature of the air is raised only 700 degrees. This shows that part of the air which passes through the recuperator is not used in the combustion of the gas whose products of combustion are exhausted through the recuperator. Of course, there are other reasons for part of this apparent discrepancy in temperatures, such as differences in the specific heat of flue-gas and air, and radiation and leakage losses. As a matter of fact, the recuperator is actually working more efficiently in the second case than in the first, for the reason that a greater rate of heat exchange takes place when the difference in temperature between the air and flue-gas is greater. In addition to this, the amount of gas burned in the kiln in the second case was almost double that of the first.

The next important question that is always asked is in regard to leakage. High velocity is desirable on both the air and the flue-gas sides of the tube walls of a recuperator, in order to sweep aside the film of stagnant gases which forms the main resistance to the flow of heat. But high velocity requires the use of high pressure, and pressure tends to cause leakage. Our recuperator is similar to most designs of the high-velocity type, in that the air is blown through under fan pressure, and the gases are exhausted through the recuperator by means of suction from a fan or stack. The point of highest pressure coincides with the point of maximum suction, and in our case amounts to more than 1.5 inches of water.

At a number of times during the past year we have taken CO_2 readings of flue-gas entering and leaving our recuperators, and the indicated leakage, including any infiltration of air from the atmosphere to the suction side of the tubes, runs from one to five per cent. of the amount of air blown through the recuperator. We, of course, took particular pains to prevent this leakage when we installed the tubes, and there has been little cause for them to loosen up since, due to the fact that the recuperators are used on a continuous kiln which has shut down only about 15 times during the past year.

When the cost of different tube materials was compared, we found that a tube made of ¼-inch high-temperature metal cost about the same as a carborundum tube ¾ of an inch thick and having the same length. We anticipated higher flue-gas temperatures, and selected the carborundum because of the danger of burning out the

metal tubes if the cold air supply should fail for a moment. The carborundum material has a lower coefficient of expansion than the metal, and therefore should not loosen up so easily under changing temperature conditions. The tubes were glazed to prevent oxidation at low temperature, and up to the present time have shown no indications of either oxidation or cracking.

When we checked up the cost of high-velocity, tube-type recuperators with that of the low-velocity refractory type, we found that the unit built of the higher priced material was actually the cheapest. The cost of a square foot of heat-transferring surface was higher for the carborundum or metal tubes, but the rate of heat flow was so much greater that the size of the recuperator was cut down to about a third of that of the refractory tile outfit. Great savings were also made in excavation, and in building space requirements, which happened to be particularly important in this instance.

This summary gives a brief history of our recuperator experience, without going far into figures and details. Whether the same results can be obtained in the steel industry is another question.

C. D. Smith:* According to my experience with recuperators there is quite likely to be an error in the indicated temperature of the preheated air, due to radiation from the furnace, unless the thermocouple is protected from such radiation.

Victor Windett:† Mr. Fitch stated that the "conversion" cost per ton of coal in making producer gas was $1.50 a ton. I think that there are many steel-works engineers and operators present who can show costs of not more than two-thirds of this figure. The engineer who informed me that he was responsible for this figure added that it was based on the operation of a large installation of hand-fired and hand-worked producers which I believe were installed about 1910.

While present at this meeting a steel-works engineer has given me a coal-conversion cost as low as 60 cents a ton. A small plant using one eight-foot mechanical gas producer is reported by the manager as gasifying coal at $1.15 a ton, including all overhead and capital charges. Of course, a larger plant using more coal will reduce

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†Engineer, Gas Products Division, Wellman-Seaver-Morgan Co., Cleveland.

this figure materially, as one gas man will attend to four producers.

In comparing the performance of different kinds of equipment or methods the basis of comparison should be similar; that is, of contemporaneous periods of development, at least.

W. H. FITCH: I used a figure of $1.50 a ton because a steel-plant operator gave me the figure and said I would be safe in using it. The sales engineer gives a certain figure to cover overall operating costs of his equipment and very frequently in practice this cost is doubled by reason of disadvantageous operating conditions. A lower cost than the $1.50 above mentioned would not spoil the picture.

W. DYRSSEN:* There are a few points in relation to the application of recuperators to the open-hearth furnace in which I differ radically with Mr. Fitch. I have tried for several years to make a good heat balance in order to find out exactly what happens to the heat-units in the open-hearth furnace. I have found the subject very elusive, but there are a few facts which I have discovered. One of these facts is that we can not take more heat away from the waste gases from the open-hearth furnace than the air which enters the furnace is able to take up. In other words, there is a fixed relation between the quantity of waste gases and air, and the amount of heat that can be transferred from the waste gases to the air in the regenerative system. For instance, if the quantity of waste gases is three times as great as the quantity of air it would be impossible to utilize more than about one-third of the heat in the waste gases, even if we made the checker chamber as big as this hotel. This is the condition which we have to face in the present open-hearth furnace.

The quantity of waste gases is anywhere from two to four times the quantity of air which enters the furnace. This statement holds true for all kinds of fuels. It is true that great improvements have been made lately in the ratio of waste gases to air, by making the open-hearth furnace as tight as possible, in order to prevent infiltration of air into the system, but the improvements attainable seem to have a limit which is very far from the ideal.

Mr. Fitch made a statement that the waste gases could be cooled down from 1400 degrees to about 500 degrees F. by the installation

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of recuperators, and for the reason just mentioned I do not think that such an ideal condition could be reached at all—in fact, I think that the temperature of the total waste gases can be reduced only a few hundred degrees.

There is also another thing in connection with the open-hearth furnace which I think it is worth while to mention. The gases coming from the open-hearth checkers with the temperature of 1400 degrees can not be considered as waste gases coming from a furnace at 1400 degrees. The temperature of the gases from the checkers will depend upon what happens in the checkers themselves, and if we introduce hot air into the checker chambers we upset the balance of the heat in the checker chambers so that the gases will be hotter, and we must, therefore, study carefully the balance of the open-hearth furnace system as a whole before we can get an idea of what can be gained by the installation of a recuperator.

The only way that we can return more heat to the open-hearth furnace by the installation of a recuperator is to raise the temperature of the air after it has passed through the checker chambers or at the entrance into the furnace hearth. We do not have any reliable data on the actual temperature of the air entering the hearth in the present open-hearth furnace, but it is likely to average something like 2000 degrees F., with an average temperature of waste gases leaving the hearth of about 2700 degrees F. If this is so, we might expect, by the installation of sufficient checkers and recuperators, to raise the temperature of the air about 350 degrees, or to about 2350 degrees F. This temperature rise does not correspond to more than a few per cent. of heat in the fuel. This relatively small gain in percentage of fuel will, however, probably have a very great influence on the working of the furnace, as it will increase the flame temperature in the furnace considerably and will make more heat available in the furnace itself, and there will probably be a considerable gain in tonnage and a corresponding reduction in fuel required per ton of steel.

We can not, however, expect to utilize more than a portion of the heat in the waste gases. We should, therefore, not attempt to take more than a certain portion of the waste gases through a preheater, because it is necessary to use an exhauster to pull the waste gases through the air heater and this exhauster can not work properly at a temperature of over 600 degrees F. Mr. Fitch shows in his

arrangement that all the waste gases are pulled through the recuperator, and I think that in such a case the temperature of the waste gases will be at least 1100 degrees F., and it would be impossible to handle the waste gases in an exhauster at this temperature. From

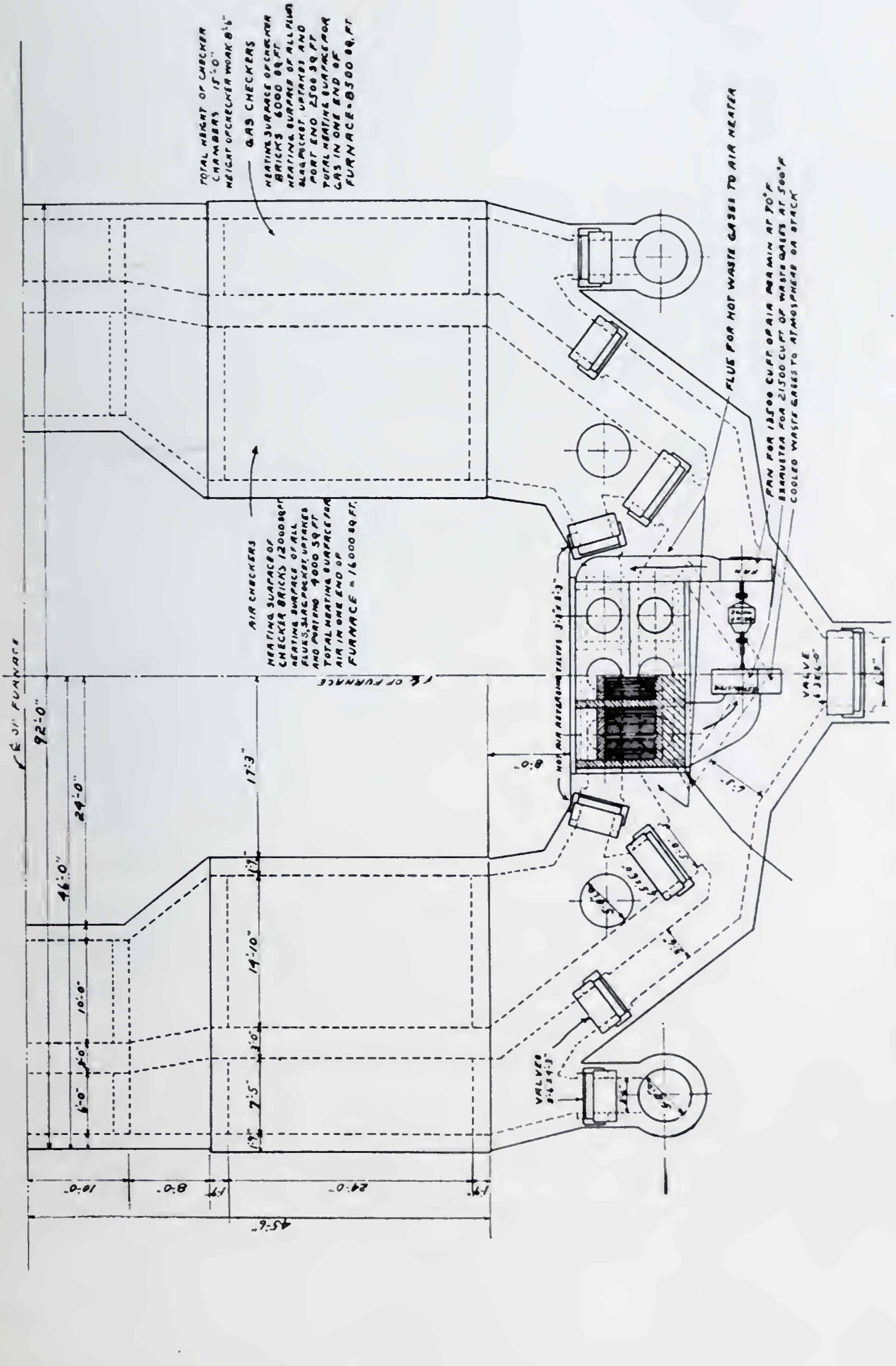

Fig. 7. Blaw-Knox Continuous Regenerative Air Heater.

this point of view alone I think that his arrangement is not practical.

The Blaw-Knox Company, with which I am connected, is manufacturing a regenerative air heater which is very well suited for application to the open-hearth furnace. This heater is built for both high and low temperatures; in fact, for much higher temperatures than those which would be encountered in open-hearth practice.

Fig. 7 shows the proposed arrangement of an open-hearth furnace with this heater. In this installation I have not proposed to change the construction of the open-hearth furnace at all. The heater is merely added as an accessory which will not interfere with the ordinary operation of the open-hearth furnace. The heater is installed between the reversing valves and the stack or waste-heat boiler in such a way that part of the waste gases can be pulled through the heater by means of an exhauster. The air is blown through the heater by means of a fan, and reversing-valves for the hot air are used for the introduction of hot air to each side of the furnace. Ordinary air-inlet mushroom valves are also shown, so that either hot or cold air can be used. This makes a very flexible installation, and at the same time it is very efficient and occupies a small space and represents an investment which is fairly small. The heater shown has a total regenerative heating surface of 29,000 square feet, which is about the same as the total regenerative heating surface in both air checkers, together with the surface in all flues, including the slag pockets. This heater is capable of heating the air to about 1100 degrees F. before it enters the checker chamber, with waste gases of about 1400 degrees F. The air heater in this installation will, therefore, relieve the checker chambers of about one-half of the work that they do at the present time, which should result in a much higher temperature of the air to the hearth. I believe that the arrangement shown indicates the lines on which we have to work in the application of air heaters to open-hearth furnaces, in order to obtain a practical installation for raising the thermal efficiency of the open-hearth furnace, and for increasing the output.

J. S. UNGER:* Regarding the question of recuperators, you can not study recuperators without taking into consideration the study of regenerators. They are intimately connected.

*Manager, Research Bureau, Carnegie Steel Co., Pittsburgh.

In a study of saving heat-units whether by regenerators or recuperators, certain things come up in practice which cause one to stop and consider the facts. For instance, we believe we can make steel more cheaply if we put a recuperator on the open-hearth furnace and reduce the temperature of the gases from the stack. The open-hearth manager says, "I have two furnaces exactly alike. On one furnace I have a stack temperature of 1200 degrees, but I can make a heat in 7½ hours; on the other furnace I have a stack temperature of 750 degrees and I require 10½ hours to make a heat." The reasons for that are easily explained. When he has a high stack temperature the combustion and draft are good, his furnace is working fast, and he makes a heat in 7½ hours. A furnace burns approximately the same amount of fuel per hour. From this it follows that low stack temperatures do not always indicate an economical furnace.

The question of adding either a low-temperature regenerator or a recuperator to the present heat-absorbing equipment of a high-temperature furnace is not new. As much as 20 years ago it was suggested to add additional regenerator chambers to the hot-blast stove of a blast-furnace, filling such chambers with metallic bricks of cast-iron. This would have the advantage of using a metal which at low temperatures absorbs heat very quickly. If, however, a high temperature were accidentally reached, the iron bricks would be rapidly oxidized or scaled, or they would absorb sulphur from the hot gases and crumble or melt down.

It has been suggested to use non-oxidizable metallic alloys. These steels are very expensive and are easily destroyed by sulphur absorption. If made of thin, light material, they are warped out of shape when the temperature becomes high. These objections will eliminate the use of metallic materials. To use carborundum tubes with their slight expansion between fire-brick walls of much higher expansion would increase the difficulty of keeping the joints tight. The construction is more complicated and expensive than the ordinary checker. Any heat-absorbing device must be of simple, sturdy construction to withstand the small puffs or explosions on some furnaces when reversing. Breaking up the gases into small streams and forcing them through small openings increases the friction, requiring better stack draft, or mechanical means, such as pressure or suction fans, to secure good combustion.

So much remains to be done in increasing the capacity of the checker chamber and directing the flow of the entering air and of the exhaust gases, to utilize all of the checker capacity, that a recuperator seems to be a means of saving heat which should be recovered by better equipment.

W. H. FITCH: I would like to reply to just one thing. Dr. Unger spoke of the expansion and contraction of carborundum and fire-clay brick. We did take this feature into consideration more seriously when we built the recuperator than now, for the following reasons: After a year of operation there is practically no opening up where the carborundum tubes tie into the fire-brick. That is an important finding. The furnace gas enters the recuperator at 1500 degrees F. The tube terminal walls, of which there are eight, two for each bank of tubes, are just as rigid as when they were built. This is due to the very slight difference in coefficients of expansion of fire-clay and carborundum at the temperatures in question. While the temperature in the first bank is the maximum, the last bank going to the stack has a very low gas temperature, therefore making a very low average and one that will withstand a considerable amount of work, with a very small repair cost.

Regarding checkers, we do not say that we propose to eliminate this feature altogether, but rather to use it in conjunction with the recuperator, and have the regenerator capacity only that which is necessary to clean the furnace gases of oxids in the molten or plastic form. The dust in powder form is easily disposed of if deposited on the tubes. This dust can not interfere with the flow of air through the tubes, the inside of which is free from furnace gases at all times.

T. J. MCLOUGHLIN:* The Engineers' Society of Western Pennsylvania is indebted to the author of the paper to which we have just listened for opening up to us a new vista; for suggesting economies which are now of vital import to the steel industry. If we turn back to those halcyon days, well within the memory of many who are present, when natural gas could be purchased for industrial use for from five to eight cents per thousand cubic feet, and coal, with an ash content of from four to six per cent. and a sulphur content of from

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0.6 to 0.7 per cent., could be procured for 80 cents a ton, delivered, we realize that there was no incentive to fuel economy, since the cost of apparatus with its interest, depreciation, operation, and maintenance charges would more than offset any saving in fuel cost which it might effect. It was in those days that many of our present open-hearth plants were built, and these, consequently, have room for neither waste-heat boilers nor increased regenerative capacity, and it is to these plants that recuperation offers an opportunity for fuel economy that can be obtained in no other way.

Discussion of the stack temperatures of open-hearth furnaces is of no value in determining the efficiency of combustion, unless analyses of fuel gas, exit port gas, and stack gas are also available. If an open-hearth furnace has sufficient stack capacity, a temperature of 500 degrees F. can very readily be secured by opening a hole in the base of the stack for air infiltration.

I have seen many open-hearth furnaces with stack temperatures of 800 to 850 degrees, with gas leaving the regenerators at temperatures of 1600 to 1700 degrees. In open-hearth furnaces using regenerated producer gas, the temperature of the waste gases leaving the gas checkers is never below the temperature of the incoming fuel gas.

The latest trend of producer-gas practice is to use the hot unregenerated gas, since the increase in sensible heat due to regeneration is partly balanced by the deposition of hydrocarbons from the producer gas in the gas regenerative chamber, and consequent loss of calorific value. One of the most potent sources of fuel inefficiency in open-hearth furnaces is air infiltration.

In considering the possibility that the sensible heat of the waste gases of an open-hearth furnace may be returned to the furnace itself, instead of absorbing it in steam-generating apparatus, it must be remembered that there is a limit. To have all the sensible heat above 500 degrees F. in the outgoing gases returned as sensible heat with the incoming air is impossible in open-hearth furnaces fired with producer gas, because refractory material necessary to withstand the resulting temperatures is not now commercially available. To show the practical limit to which this may be carried I have prepared (in Table I) a heat balance for such a furnace. Of course, every such heat balance must be founded on present-day practice, and the one which I have worked out is based on the following conditions:

1. That a temperature difference of 500 degrees F. exists between the theoretical and actual flame temperatures of a gas above 3000 degrees.

2. That an average figure of 26 per cent. of the total heat entering the furnace is absorbed by the materials in the hearth; used in bringing about endothermic reactions; or lost in radiation from the hearth or port ends before the products of combustion enter the regenerative chamber.

3. That air infiltration, amounting to 25 per cent. by weight of the products of combustion leaving the exit port, occurs between the exit port and the entrance to the regenerators.

TABLE I. HEAT BALANCE OF PRODUCER-GAS-FIRED OPEN-HEARTH FURNACE

	Unit	Basis of 1 cubic foot of fuel gas	Million B.t.u. per hour	Percentage heat in fuel gas
1. Tons of steel produced per hour..	tons	10		
2. Total gross heat in fuel (3+4+5)	B.t.u.	176.67	52.19	100.00
3. Calorific heat in fuel............	B.t.u.	149.71	44.23	84.74
4. Total sensible heat in dry fuel....	B.t.u.	24.44	7.22	13.83
5. Total sensible heat in moisture in fuel....................	B.t.u.	2.52	0.74	1.43
6. Fuel per hour..................	cubic feet	295,420		
7. Temperature of fuel............	degrees F.	1300		
8. Total gross heat in air for combustion (9+10)..............	B.t.u.	81.43	24.06	46.09
9. Sensible heat in dry air preheated	B.t.u.	79.81	23.58	45.17
10. Sensible heat in moisture in air preheated..................	B.t.u.	1.62	0.48	0.92
11. Cubic feet of air for combustion..	cubic feet	2.1462		
12. Temperature of preheated air....	degrees F.	2000		
13. Percentage of excess air.........	percentage	71.696		
14. CO_2 addition from bath.........	cubic feet	0.0930		
15. Temperature of CO_2 upon addition	degrees F.	3000		
16. Heat added by CO_2 addition.....	B.t.u.	10.40	3.07	5.89
17. Total gross heat in fuel and air at uptakes..................	B.t.u.	268.50	79.32	151.98
18. Theoretical flame temperature...	degrees F.	3600		
19. Actual flame temperature........	degrees F.	3100		
20. Volume of products of combustion leaving exit port of furnace. No infiltration...............	cubic feet	2.8597		
21. Air infiltration between exit port and entrance to checkers (based on weight of exit gases from furnace)....................	percentage	24.66		

TABLE I. HEAT BALANCE OF PRODUCER-GAS-FIRED OPEN-HEARTH FURNACE—(*Continued*)

	Unit	Basis of 1 cubic foot of fuel gas	Million B.t.u. per hour	Percentage heat in fuel gas
22. Air infiltration between exit port and entrance to checkers (volume of air)	cubic feet	0.7516		
23. Volume of waste gases entering regenerators	cubic feet	3.6113		
24. Heat absorbed by bath and lost to radiation and unaccounted for before entrance to checkers (percentage of total heat)	percentage	26.00		
25. Heat absorbed by bath and lost to radiation and unaccounted for before entrance to checkers.	B.t.u.	69.81	20.62	39.51
26. Heat available at entrance to regenerator (percentage of total heat input)	percentage	74.00		
27. Heat available at entrance to regenerators	B.t.u.	198.69	58.70	112.46
28. Temperature of waste gases at entrance to regenerator	degrees F.	2400		
29. Temperature necessary at entrance to regenerator to preheat air to 2000 degrees F.	degrees F.	2400		
30. Infiltration of air through checkers	percentage	0		
31. Heat radiated from checkers (percentage of total heat input)	percentage	18.00		
32. Heat radiated from checkers	B.t.u.	48.33	14.28	27.36
33. Heat absorbed by air to raise temperature to 2000 degrees F.	B.t.u.	75.99	22.45	43.01
34. Heat available at exit from checkers	B.t.u.	74.37	21.97	42.09
35. Temperature of waste gases leaving checkers	degrees F.	1016		
36. Infiltration of air between exit from checkers and stack (based on weight of gases leaving furnace)	percentage	12.50		
37. Infiltration of air between stack and exit from checkers	cubic feet	.3810		
38. Heat radiated from flues (percentage of total heat)	percentage	5.00		
39. Heat radiated from flues	B.t.u.	13.43	3.97	7.60
40. Volume of stack gases	cubic feet	3.9923		
41. Stack temperature	degrees F.	788		
42. Total air infiltration (based on weight of exit port gases at inlet side of furnace)	percentage	0		
43. Outlet side of furnace	percentage	37.16		
44. Cubic feet of infiltrated air into system per unit of fuel	cubic feet	1.1326		

4. That the checker chambers are tight and allow no air infiltration.

5. That an average of 18 per cent. of the total heat entering the furnace is lost in radiation from the checkerwork.

6. That the air infiltration between the exit from the checkers and the stack is approximately 12½ per cent. by weight of the products of combustion leaving the furnace.

7. That an average of five per cent. of the total heat input to the furnace is lost in radiation between the stack and the exit from the checkers.

This balance shows that, with a flame temperature of 3100 degrees F., beyond which it is inadvisable to go with present refractories, 788 degrees F. is the lowest point to which the stack temperature may be reduced by returning the sensible heat in the waste gases to the furnace itself.

With the present types of regenerators and the heat transfers obtained in open-hearth practice, it would require 27,500 square feet of heating surface to secure this result. Many existing plants could not possibly install this and perhaps, as has been suggested, with the available space the desired result could be accomplished with recuperation. Two difficulties, however, might be encountered in such an installation. The dust content (which I have found to vary between 1.066 and 2.215 pounds an hour on a 75-ton furnace) might settle out in the recuperator, thus clogging it up. The other difficulty, which would be found only in adapting recuperators to existing installations, is that the draft loss through the combined regenerator and recuperator would be beyond the stack capacity and therefore tend to slow up the furnace. This is especially true toward the end of a campaign when the regenerative chamber would be clogged.

AIR PREHEATERS FOR BOILERS*

By R. E. Butler†

To discuss any subject very intelligently from an operating engineering standpoint, as against a strictly structural or design standpoint, a considerable amount of actual data covering the operation of the apparatus under consideration should be available.

While air preheaters have been in use to a considerable extent abroad and in marine practice for a number of years, and in this country for a lesser time, the amount of reliable data available from actual operation is remarkably scanty. It is true that a number of tests of air heaters have been, and are being, reported, but these are under such a widely varied set of operating conditions that data can not be said to be sufficient to stabilize the art.

The use of air heaters is certainly not new. They were used in connection with metallurgical furnaces abroad as early as 1829, and in England alone, by 1839, there had been issued over 50 patents covering air preheaters. The early patents based their claims for the advantages of preheated air almost solely upon smoke elimination, and it was not until the early '70's that the possibility of increased efficiency resulting from the use of preheat seems to have been considered. The first air heater to be installed in connection with stationary boilers in this country was apparently made in a mill in Massachusetts in 1879.

Development of air heaters was undoubtedly slower in this country than abroad primarily because of the relatively lower fuel costs. These costs soon increased, however, and the demands for higher efficiencies and the maintaining of such efficiencies at higher rates of steam output necessitated the consideration of heat-absorption apparatus other than boilers. The two types of apparatus considered were economizers and air heaters—or as they are called abroad, air economizers. It is not the intention to discuss here the relative merits of the one as against the other. There is, however, one point that applies as yet to central-station, rather than to industrial-plant installations, in connection with the advisability of an air heater as compared with an economizer installation, that may be of interest.

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In the central-station, the use of bleeder steam for feed-water heating has within the past few years become more and more generally accepted as representing the best practice from the standpoint of plant heat balance. This bleeding is done in two, three, and, in some cases, four stages. In many instances the feed-water temperature leaving the last bleeder heater is sufficiently high to make questionable the advisability of an economizer installation—that is, the temperature range through which an economizer could properly function would be too limited. It has been general practice to maintain feed-water temperatures leaving economizers at a point at least 50 degrees below the temperature due to the pressure within the boiler it serves under the worst conditions of operation that could occur. Under such conditions, if the feed-water temperature entering the economizer is as high as 300 or 350 degrees, the possible rise through the economizer may not be sufficient to justify the expense and possible complication of an economizer installation. Here, then, if additional heat-absorption apparatus is required to give the necessary overall efficiency, the problem may be solved by the use of air heaters.

The speaker has no means of knowing the extent to which air heaters are being used in this country to-day; there are too many manufacturers of such apparatus building and selling them. That the extent is considerable, however, is indicated by the number of installations made by the company with which the speaker is connected and, in considering these figures, it is to be remembered that this company has offered air heaters only with boilers of its own manufacture. Since the latter part of March, 1923, when the first air heater was offered, the company has installed or on order 66 air heaters on 22 different contracts, in connection with boilers containing something in excess of 1,080,000 square feet of heating surface, the air heaters containing slightly over 1,240,000 square feet of surface.

The ideal air heater is one that will give a maximum rate of heat transfer, minimum draft loss, and minimum leakage; will occupy the least space, and be most readily cleaned.

The first two of these factors are intimately related. While the form of the channels for passage of air and gas has a bearing on the rate of heat transfer, this rate is primarily a function of gas and air velocities, and such velocities in turn govern draft loss on both the gas and air sides. Obviously, there is some velocity, and correspond-

ing heat-transfer rate, which can not be exceeded, in view of the fact that the power required to overcome the increased draft loss would be more than sufficient to offset the gross increase in efficiency. The questions of space occupied, tightness, and ease of cleaning are features of design, and vary in the preheaters of different manufacturers.

Air preheaters, as to-day offered, may be classed under two general types—plate and tubular. The rotative regenerative heater is only one form of a plate-type heater. Advantages are naturally claimed for both types, and, to some extent, such advantages may be said to be largely a matter of personal opinion of the user. If either type is properly designed, equal amounts of preheating surface should give equal heat absorption for a given draft drop. Advantage of one type over the other then becomes a question of accessibility, ease of cleaning, possibility of keeping it tight, ease of replacement of elements needing renewal, and general cost of maintenance. The speaker's company has manufactured heaters of both types, but to-day is offering tubular heaters only, believing that this type best fills the mechanical requirements of design given above.

We might say here, in connection with leakage (incidentally the tubular type of heater, on account of its expanded-joint construction, should offer the least possibility of leakage), that regardless of the care taken to prevent, or minimize, leakage in the preheater itself, by reason of air infiltration through the boiler setting and connecting flues, there is in the products of combustion a certain amount of air that has never been passed through the preheater. In stoker-fired practice, the weight of air heated is probably some 75 per cent. of that appearing in the products of combustion, while in pulverized-fuel practice this weight will vary from 85 to 90 per cent., depending upon the type of burners used and whether central or unit mills are used.

The question of metal temperatures in air preheaters is different from that in economizer practice. In the latter, the tube temperature is approximately that of the water within the tube; whereas, in an air heater, provided transfer rates are the same on the gas and air sides of the flow channels, the metal temperature will be the mean of the gas temperature and the air temperature at any given point.

The upper limit of temperature to which the hot end of an air heater may be expected to stand is fixed by the temperature which the metal entering into the construction of the heater will stand; that is,

assuming a counter-flow heater, the mean between entering gas temperature and exit air temperature can not exceed the safe temperature from the standpoint of the life of the metal employed in the construction of the heater.

The lower limit of gas temperature is fixed by the dew-point of the particular gas that is to pass over the heater; that is, the mean temperature of entering air and exit gas, or the temperature of the cold end of the heater, must be kept above the dew-point of the gas. Otherwise, condensation will take place, and trouble from corrosion will follow. It is improbable, however, that sufficient air-heater surface could be justified to bring the cold-end metal temperature to a point where trouble from this source could be expected.

There is certainly no agreement among engineers as to the air temperatures either advisable or allowable with preheat. Such temperatures naturally will vary widely with the fuel, the method of firing, and design of furnace, but there is a considerable divergence of ideas even for a given set of conditions.

The use of preheated air for combustion naturally leads to increased furnace temperatures. Such increase is never equal to the amount of rise of air temperature and will vary with a number of conditions. While no definite figures are available, it would appear that the actual increase in furnace temperature, due to the use of preheated air, is in the order of from one-tenth to one-third of the rise of air temperature through the preheater. These figures are based on the same combustion conditions (as to CO_2) in the case of both normal and preheated air temperatures, and represent but a small change in furnace temperature. On the other hand, under most conditions, the use of preheated air permits the maintenance of better combustion conditions (as regards CO_2) than where no preheat is used, and here there is a possibility of appreciably increased furnace temperatures.

Increased furnace temperatures mean greater tendency toward trouble with furnace refractories, and, in the case of stoker firing, increased cost of stoker maintenance. Furthermore, with some coals, increased furnace temperatures will increase slagging troubles to an extent which would not justify air heaters. Again, preheat may affect the action of some coals on the grate. We know of an instance of middle western coal burned on a blast, chain-grate stoker, where, if an air temperature above 250 degrees was used in the forward com-

partment, the coal had such a tendency to mat on the front of the grate that satisfactory combustion could not be obtained.

There is one installation fired with underfeed stokers and without any furnace cooling surface where preheated air up to 350 degrees was used without developing any difficulty either with the stoker or with furnace brickwork. In the same plant, another unit with identical furnace and stoker used preheated air at a temperature of 600 degrees, and here trouble did develop. The primary trouble was with the stokers, though this was overcome by a change in the method of stoker operation. Brickwork trouble did develop from the high furnace temperature, and water-cooling surface is now being installed in the furnace of this particular unit. Here we have an instance of a refractory furnace which from the standpoint of brickwork trouble gave no trouble with preheated air at 350 degrees, but did give trouble with air at 600 degrees. At what temperature between these two points trouble might be expected to develop can not yet be stated from our experience. Probably the safest thing to do where the action of the coal with preheat is not known is to provide for by-passing some of the air or gas to the preheater to control the preheat until the safe degree of heat is determined.

It is probable that with oil or pulverized coal the maximum allowable preheat temperature would be higher than with stoker-fired boilers where no cooling surface is used in the furnace, if only because brickwork trouble would limit the maximum temperature; whereas, with stokers, a stoker maintenance or the action of a particular coal on the grate under preheat conditions must be considered.

With the increased rates of steam output demanded from a given amount of boiler heating surface, destruction of furnace brickwork has increased tremendously even without preheat, and where preheated air is used this trouble is bound to be aggravated. To protect furnace brickwork under present-day conditions of severe temperature, side-wall cooling is coming more and more to be accepted as the best practice—certainly in the larger boiler units and those from which high rates of steam output are required. This side-wall cooling has been both by air and by the use of water-cooling tubes, either bare or protected in some manner by refractory material. The tendency is apparently toward water cooling rather than air cooling of furnace walls.

From the standpoint of protection of furnace brickwork, side-wall cooling can to-day be stated as giving satisfactory results. Higher furnace temperatures (higher CO_2) can be maintained without refractory trouble with or without the use of preheated air, but it is where high preheat is used that the cooling surface shows to greatest advantage; or, conversely, air preheaters giving high temperatures will show the most satisfactory return where furnace-cooling surface is used.

The maximum temperature of air that can be used, even with cooled furnaces, is dependent upon a number of factors. In stoker-fired units where water-cooled furnaces are installed, the limit in allowable preheat and furnace temperature will probably be determined by stoker-maintenance costs and slagging troubles, the latter depending primarily on the fusing temperature of the ash in the coal used. In the case of pulverized-fuel furnaces with cooled walls, the limit will probably be set by the slagging difficulties encountered in the furnace itself and in the boiler tubes.

The increase in efficiency to be expected through the use of an air preheater is, of course, dependent upon the particular design of heater used, the rate at which the boiler it serves is operated—this as affecting the temperature of gas entering the heater, the amount of air-heater surface installed, the class of fuel used, and the methods of burning such fuel. The last two items must be given consideration because of the wide variation in gas weights with different fuels burned by different methods, per boiler horse-power developed.

The number of factors involved makes it almost impossible to make any comprehensive statement as to increase in efficiency due to the use of preheat, and reported results show increases anywhere from 4 to 12 per cent.

The gain in efficiency due to the use of preheated air may be greater than that indicated by the drop in gas temperature through the heater. The higher furnace temperature resulting from the use of preheat increases the efficiency of the boiler through the improvement in combustion conditions. Furthermore, at least with moderate degrees of preheat in stoker-fired boilers, the loss in combustible in the ash has been shown by test to be lower.

That the increase in efficiency is greater than corresponds to that measured by the heat absorption of the air heater, has actually been

shown in authentically reported tests.* These tests were with moderate degrees of preheat (300 to 350 degrees). Theoretically, the same should be true for higher degrees of preheat, but available information is not sufficient.

In many cases the use of preheated air with the resulting increased efficiencies allows boilers to be operated at higher rates of steam output; that is, rates at which a boiler alone would show an efficiency lower than that allowable from the standpoint of commercial efficiency. Furthermore, where air heaters are used, the efficiency-output curve, within reasonable limits, will be flatter than the corresponding curve for a boiler alone.

Conditions under which air heaters can be installed with boilers under which blast-furnace gas is to be burned, are somewhat different from those in the case of coal-fired boilers.

From the standpoint of furnace temperature, blast-furnace gas is the ideal fuel for use with preheated air. With blast-furnace gas, furnace temperatures are comparatively low, and high degrees of preheated air can be safely used without the necessity of furnace cooling, without trouble from furnace brickwork.

As regards design of air heaters—because of the larger ratio between weights of products of combustion and air to be heated—there is a limit to the amount of heat that can be abstracted from such products and returned to the air. In the case of coal-fired boilers, the weights of air and products of combustion are approximately the same; whereas, in the case of blast-furnace gas, this ratio is about two to one. This ratio of weight of combustion products to that of air to be heated also makes necessary a change in the general design of air heaters as to the average areas of channels for the passage of air and gas. In coal-fired boiler units, for approximately equal draft losses on the gas and the air sides, the areas of flow may be made approximately the same. In the case of boilers fired with blast-furnace gas, the weight of products of combustion, relative to the weight of air to be heated, is such that for approximately equal draft losses on the gas and air sides, the flow areas for the former must be made from 1½ to 2 times that for the latter.

As far as the speaker knows, there is in operation only one

*Recent Developments at Colfax Station, Duquesne Light Co., by C. W. E. Clarke. Trans. A.S.M.E., v. 47, p. 1015.

installation of air heaters made with boilers fired with blast-furnace gas—that of the Edgar Thomson Works of the Carnegie Steel Company. Mr. Edgar has kindly given us some figures of the performance of these preheaters, and, while they are perhaps not as complete as will be available later, they are of interest. These air heaters are set with twin Stirling boilers, each with 22,248 square feet of heating surface, over one furnace. Two heaters, set overhead, are made up of 37 rows of four-inch tubes, 20 feet long, and 13 rows deep. Each heater contains 10,082 square feet of external surface (the air side) and 9400 square feet of internal surface (the gas side). The gases pass vertically through the tubes, and the air makes four horizontal passes across the tubes.

One unit fired with blast-furnace gas was in operation for some three months prior to October 1, 1926, and a second unit was operated for approximately two months prior to that time. The air heaters incidentally were not cleaned during these periods of operation. The ratings at which the first unit was operated for July, August, and September were 150, 150, and 165 per cent., respectively. The gas temperatures entering the air heater for the same months were 770, 675, and 630 degrees, respectively. The only record of CO_2 leaving the heater was for the month of August and is given as 18.4 per cent. While this percentage may be considered low for blast-furnace gas, it might be stated that the readings were taken after the gases had passed through the boiler, the air heater, and the breechings. The decreasing gas temperature entering the air heater in successive months in the face of as high or higher rates of output is undoubtedly due to betterment of combustion conditions in the boiler furnace resulting from greater familiarity with the equipment on the part of the operators. The exit gas temperatures from the preheater for these three months were 530, 465, and 440 degrees, respectively, and the corresponding air temperatures to the furnace, 430, 445, and 430 degrees. Any apparent discrepancy between drop in gas temperature and rise in air temperature may be explained by the fact that at the first of October the air heater had not been lagged.

The fact that the air temperatures entering the furnace are approximately the same for the operating period of three months would seem to indicate that there is no falling off in air heater efficiency over a considerable period, and hence no appreciable accumulation of dust

on the interior of the tubes. It is possible that, in operation, the gas velocity within the tubes is sufficiently high to sweep them clean.

The boiler unit to which this preheater was attached was taken down about October 14. There was a considerable accumulation of dust on the top tube sheet—in peaks about one foot high—which was readily removed. There was also a deposit of not over 3/64 of an inch on the interior of the tubes, but, since the air temperatures had not decreased over a period of three months, it is possible that this accumulation was deposited when the boiler was being taken off the line.

Though no information is available regarding increase in furnace temperature due to the use of preheated air, no difficulty has been experienced due to such preheat, either from furnace refractory, slagging of dust in the furnace, or slagging on boiler tubes. The gas burned is unwashed and comes to the burners at a temperature of approximately 400 degrees. It is believed by the operators that it will never be necessary to shut down a boiler because of trouble resulting from slagging in the furnace, since no difficulty has as yet developed in removing the accumulated dust through the furnace hoppers.

In this same plant there are two other boilers and air heaters identical with the units fired with blast-furnace gas. These are equipped with underfeed stokers and have been in operation some four months. No records of gas or air temperature are available from these units. While no refractory troubles have developed in the furnaces of these boilers, a certain amount of stoker trouble has been experienced in the way of burning of stoker parts. This difficulty, however, is being overcome through a change in the methods of stoker operation from those employed where no preheat has been used.

There is also installed in the Edgar Thomson plant a unit identical in boiler section and air heater, but fired with coke breeze on a blast, chain-grate stoker. This unit has been in operation intermittently for some six months at an average rate of some 130 per cent. The gas temperatures in and out of the air heater for this unit are reported as 680 and 434 degrees, respectively, while the air temperature leaving the heater is given as 282 degrees. Here we have a direct example of the effect of the ratio of weight of products of combustion to the weight of air to be heated on the rise in air temperature to be expected with blast-furnace-gas firing as compared with other fuels.

During the six months' operation of the boiler fired with coke breeze the air heater was cleaned once with a wire brush. Though a considerable dust accumulation was noted, the decrease in rise of air temperature was not appreciable.

With the unit fired with coke breeze, in spite of the comparatively low air preheat temperature, considerable trouble has been experienced with both furnace refractories and stoker maintenance, and this has not yet been eliminated. In view of the fact that refractory trouble in the underfeed, stoker-fired furnaces has not been entirely eliminated, it may be a question of furnace design rather than one of air temperature.

The speaker believes he can safely state that the operators of the plant described are entirely satisfied with their air-heater installation, though the period of operation is comparatively short. There has been no trouble with the air heaters themselves and, as yet, no maintenance charge. Examination so far has indicated that such dirt as has accumulated in the tubes has been of a dry powdery nature that can readily be removed. The operators hope to be able to run for a period of 12 months without cleaning the air heaters, and feel that it will not be necessary to take a boiler off the line simply for cleaning or repair of air heaters. Where cleaning is necessary they expect to clean with a wire brush and not to wash, as is general in most coal-fired plants.

In closing, the speaker would like to say, with some satisfaction, that the results obtained from the air heaters in this particular plant are gratifying in that they are so much in line with the performance figures predicted—decidedly above rather than below.

DISCUSSION

A. C. FIELDNER, *Chairman*:* I would like to ask Mr. Butler a question regarding the ash fusibility in connection with furnaces using preheaters. Is the clinker temperature or fusibility of ash any lower than it is in ordinary furnace practice? By clinker temperature I mean the temperature which the operator has considered a safe figure for his practice, which will vary for different coals and for different furnace and operating conditions; but does the preheated air in itself

*Superintendent Pittsburgh Experiment Station, and Chief Chemist, U. S. Bureau of Mines.

make any great difference in practice on account of the kind of ash you want?

R. E. BUTLER: Experience along these lines is yet rather limited. We have an installation where the operators claim exactly opposite results. Apparently where a moderate preheat, not exceeding 300 degrees, is used in connection with underfeed stokers, there is no serious trouble from slagging or clinkering, and what little trouble there is can be readily overcome. I know of one plant where they are using preheated air at about 300 degrees, and the firemen claim they have less trouble from clinkering and slagging than where no preheat is used on stokers in the same plant burning the same coal. Theoretically, we would anticipate no trouble in the furnace from preheat. Apparently, however, the trouble is not serious with coals in this territory and where the preheat is moderate. Further west, with the grades of coal they have there, we have had an appreciable amount of trouble due to the low fusing point of the ash. Also in that section the high sulphur content in the coal tends to cause corrosion in air heaters unless care be taken to avoid this.

W. DYRSSEN:* I do not think that Mr. Butler's specification of air heaters is right and I do not think that regenerative air heaters should be omitted in a paper of this kind. The Blaw-Knox regenerative air heater, which has been discussed several times to-day, offers many advantages also for low temperatures and for application to boilers. I do not want to discuss these advantages here, but I would rather like to hear some practical men, who have had experience with air heaters, discuss this paper, and I think this will be of more interest to our Society than to hear discussions by manufacturers of air heaters.

A. C. FIELDNER, *Chairman*: There are a good many questions of interest which I am sure can be brought out in a further discussion of the general subject of recuperators and materials for recuperation. Is there any one who can give us any information on the status of heat-resisting alloys? That problem was mentioned by Dr. Unger, in discussing Mr. Fitch's paper to-day. What is the limiting temperature?

*Chief Engineer, Furnace Equipment Department, Blaw-Knox Co., Blawnox, Pa.

R. E. Butler: We have had considerable experience with chromium alloys for resisting temperature, and in my experience I have found that a high-chromium alloy can be heated to a sustained temperature slightly in excess of 1500 degrees. The next best alloy I feel will stand a sustained temperature about 300 degrees lower, or around 1200 degrees; that is, a chrome alloy will stand a metal temperature about 300 degrees higher than any other commercial alloy yet developed. Conditions, of course, affect these temperatures and the figures cited are very general. Of course, chromium alloy at 1500 degrees may mean a very much higher gas temperature around the metal tubes; for instance, 1800 degrees gas temperature, or higher, depending largely on the temperature of the gas on the inside of the tube.

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the William Penn Hotel, Tuesday, December 14, at 4:10 P. M., President W. E. Fohl presiding, Messrs. Ladd, Hunter, Spellmire, Covell, Fieldner, Humphrey, Rice, Johnston and the Secretary being present.

The minutes of the last meeting, held November 16, were approved without reading.

Applications from the following applicants, having been published to the Society, pursuant to the action of the Board, were elected to membership:

MEMBERS

Arvidson, C. G.
Hellmund, R. E.
Kirk, R. L.
Lewin, Francis A. W.
Mundo, C. J.
Phillips, L.
Powel, C. A.
Rittman, Walter Frank
Roughen, R. H.
Schuchert, Joseph S.
Sborigi, Guido V.
Ward, Vernon Champlin
Whitwell, George E.

ASSOCIATE MEMBERS

Kendall, Theodore H.
Lovett, S. C.
McCullough, John Lewis
Metzger, William Fred
Tredway, Alexander C.
Wilson, Howard Mitchell

ASSOCIATES

Anderson, Walker
Bingay, R. V.
Cooke, M. W.
Downer, Charles B.
Ghen, Melville W.
Hill, Charles M.
Knaell, Kenneth K.
McElheny, George B.
McKee, Frederick Chadwick
McGrath, M. H.
Ousler, G. W.
Sinclair, C. T.
Perkins, E. E., Jr.
Ronay, J. L.
Roth, J. D.
Rudd, H. H.
Sill, Edgar T.
Sutherland, George
Walworth, Stanley L.

JUNIORS

Greg, Victor V.
LeBaron, George I.
Peterson, V. H.

STUDENT JUNIOR

Smith, I. L.

Applications for membership were received from the following gentlemen and their names ordered published to the Society. Assignment to the various grades of membership is as follows:

MEMBERS

Fairchield, F. P.
Flippen, J. P.
Furlow, J. C.
Fusca, Emil A.
Hester, E. A.
Jobke, August F.
Umstead, Elgie James
Robertson, R. N.
Whyte, Clifford R.

ASSOCIATE

Hacking, J. P.

JUNIOR

Fiedler, Marcell

The Secretary reported the death of the following members:

Daniel Carhart	Joined Feb., 1883	Died Dec. 7, 1926
W. L. Jones	Joined Mar., 1888	Died Nov. 25, 1926
W. G. Tellin	Joined Dec., 1921	Died Dec. 12, 1926

The report of the Secretary showing the financial condition of the Society at close of business November 30, having been audited by the Finance Committee, was approved.

The Secretary reported on behalf of Mr. Clifford, Chairman of the Entertainment Committee, that arrangements were being completed for the Annual Dinner, which will be held Monday evening, January 31.

The Secretary reported for Mr. Weldin, Chairman of the House Committee, an evening attendance of 480 for the month of November.

The Membership Committee held one meeting to go over applications received since the last meeting of the Board and to assign them to the various grades of membership.

In accordance with Article 5, Section 7 of the By-Laws, as no additional nominations were received, it was moved and carried unanimously that the report of the Nominating Committee as presented at the last meeting be finally approved and the Secretary instructed to send out ballots in accordance with our By-Laws.

Mr. Hunter, Chairman of a special committee appointed by the President, in accordance with action taken at the last Board meeting regarding plan of organization and co-operation with the American Engineering Standards Committee, reported that a meeting of the committee had been held, at which Mr. C. E. Skinner, President of the American Engineering Standards Committee, was present, and that it was the unanimous opinion of this committee that the Engineers' Society should co-operate in every way possible in this work, as they believed it to be of great value to the industries and to the engineering profession as a whole.

It was recommended that the President be authorized to appoint a committee of five or more members to form the main committee to carry on this work and that they in turn appoint special committees of any particular standard they may decide to try and introduce into this district. It was further recommended that in order to bring this to the attention of the Pittsburgh industries that a meeting be called at which a representative member of the Engineering Standards Committee be invited to speak, and further, that at this meeting the year books of the American Engineering Standards Committee be distributed in order to familiarize these men with the work of the committee.

After discussion, it was moved and carried that the report of the committee be approved and the President authorized to appoint the committee as suggested.

Mr. Rice called the attention of the Board to the fact that under the recent move of the Mayor and Council to cut the budget of the city for the coming year, the appropriations for the City and County Topographic Survey as approved by this Society would suffer, and recommended that inasmuch as we had approved the making of this survey, we write letters to the Mayor, City Council and County Commissioners, urging that sufficient funds for the carrying on of this work be included in the budget. After discussion, it was moved and carried that these letters be written, recommending that funds be appropriated for the work and calling their attention to its importance.

The meeting adjourned at 5:10 P. M.

K. F. TRESCHOW, *Secretary.*

ILLUMINATING ENGINEERS' SECTION

The regular meeting of the Illuminating Engineers' Section was held jointly with the Pittsburgh Section of the Illuminating Engineering Society in the Blue Room of the William Penn Hotel, Monday, December 13, at 8:15 P. M., Chairman H. L. Johnston presiding, 23 members and visitors being present.

The minutes of the last meeting, held November 15, were read and approved.

There being no further business before the Section, the paper of the evening, on "Lighting Codes," was presented by Mr. John A. Hoeveler, Manager, Engineering Department, Pittsburgh Reflector Company, Pittsburgh, Pa.

A general discussion followed the presentation of the paper.

On motion, a vote of thanks was extended to Mr. Hoeveler for his very interesting paper.

The meeting adjourned at 9:40 P. M.

K. F. Treschow, *Secretary.*

JOINT MEETING

Engineers' Society of Western Pennsylvania, General Society; Electrical Section, E. S. W. P.; and Pittsburgh Chapter, American Institute of Electrical Engineers

The four hundred and forty-third regular monthly meeting of the Engineers' Society of Western Pennsylvania was held jointly with the Electrical Section and the Pittsburgh Section of the American Institute of Electrical Engineers in the Auditorium, Chamber of Commerce, Tuesday evening, December 14, at 8:10 o'clock. Chairman George S. Humphrey was not present and Mr. Fohl presided, 500 members and visitors being present.

The minutes of the last meeting, held November 16, were read and approved.

The Board of Direction reported the election of thirteen applicants to the grade of Member, six to the grade of Associate Member, nineteen to the grade of Associate, three to the grade of Junior and one to the grade of Student Junior, and the receipt of eleven applications for membership. Thirty-four members were dropped, three deaths reported and three resignations accepted.

No further business coming before the Society, Dr. W. R. Whitney, Director, Research Laboratory, General Electric Company, Schenectady, N. Y., addressed the Society on "Research."

A general discussion followed the address.

On motion, duly seconded and carried, a vote of thanks was extended to Dr. Whitney for his very interesting address.

The meeting adjourned at 9:45 P. M.

K. F. Treschow, *Secretary.*

MECHANICAL SECTION ALL-DAY CONFERENCE

Joint Meeting With Pittsburgh Section, American Society of Mechanical Engineers

A conference was held by the Mechanical Section of the Engineers' Society of Western Pennsylvania jointly with the Pittsburgh Section of the

American Society of Mechanical Engineers, Thursday, December 16, from 9:30 until 4:00 P. M., Chairman William Shaw presiding, 158 members and visitors being present.

The papers presented were as follows: "Small Turbines," by George A. Orrok, Consulting Engineer, New York City; "Boiler Settings," by G. E. Dignan, Chief Engineer, Rust Engineering Co., Pittsburgh, Pa.; and "Characteristics of Fans," by T. G. Estep, Assistant Professor, Mechanical Engineering, Carnegie Institute of Technology, and C. A. Carpenter, Carpenter & Byrne, Pittsburgh, Pa.

The ensuing discussion was participated in by: R. E. Butler, Sales Engr, Babcock & Wilcox Co; W. D. Canan, Mech. Engr, Rust Engineering Co; H. C. Cronemeyer, Designer, Jones & Laughlin Steel Corp, Woodlawn, Pa; H. H. Downes, Dist. Mgr, American Blower Co; J. M. Lessells, Engr. in Charge, Mechanical Section, Research Dept, Westinghouse Elec. & Mfg. Co; R. E. Martin, Supt, Boiler Room, West Penn Power Co; E. B. Plapp, Engr, Mechanical Engineering Dept, Aluminum Co. of America, New Kensington, Pa; Wm. Shaw, Power Engr, Mechanical Division, Bureau of Water, City of Pittsburgh; F. M. VanDeventer, Engr, Construction Dept, H. L. Doherty Co, New York City; and the authors.

On motion, duly seconded, a vote of thanks was extended to the authors for their interesting papers.

Meeting adjourned at 10:00 P. M.

K. F. Treschow, *Secretary.*

STEEL WORKS SECTION

The regular bi-monthly meeting of the Steel Works Section of the Engineers' Society of Western Pennsylvania was held in the Reception Room, William Penn Hotel, Tuesday, December 21, at 8:30 P. M., Chairman A. C. Fieldner presiding, 33 members and visitors being present.

The minutes of the last meeting, held October 28, were read and approved.

There being no further business coming before the Section, the paper of the evening, on "Some Features of Australian Blast-Furnace Construction and Practice," was presented by Mr. David Baker, Jr., Consulting Engineer, Philadelphia, Pa.

The ensuing discussion was participated in by: S. L. Goodale, Professor Metallurgy, University of Pittsburgh; E. H. Cameron, Asst. Steam Engr, Jones & Laughlin Steel Corp; A. C. Fieldner, Supt, Pittsburgh Experiment Station, U. S. Bureau of Mines; Barton R. Shover, Consulting Engineer, Pittsburgh; L. C. Frohrieb, Pres, Federal Egnineering Co; W. H. Smyers, Inspector & Chemist, Duquesne Slag Products Co; and the author.

On motion, duly seconded and carried, a vote of thanks was extended to Mr. Baker for his very interesting paper.

The meeting adjourned at 9:14 P. M.

K. F. Treschow, *Secretary.*